MODIS Team Member - Progress Report
Marine Optical Characterizations
1991 - 1992

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NOAA/NESDIS

BACKGROUND

The numerous MODIS descopings and funding resource reductions to date have had a modest impact on the over all scope of the basic tasks originally proposed. However, they have required drastic extensions in the task schedules with all major activity beginning in 1993. The three major pre-launch tasks were to:

1. Develop and deploy autonomous marine optical buoy (MOBY) systems for calibration/validation of water-leaving spectral radiances observed by MODIS. The two primary sites were near the JGOFS time series locations at Bermuda and Hawaii.

2. Develop an at-sea bio-optical experiment team which would acquire state-of-the-art observations pertinent to the development of the Ocean Teams primary products. Plan and execute at-sea experiments in a diversity of oceanic waters.

3. Develop a series of bio-optical relationships(Chlorophyll *a*,total suspended material, PAR, etc.) for the MODIS spectral bands and provide these preliminary forms to the MODIS Ocean Team Computer Facility (MOTCF) for product algorithm development.

The NASA implementation of SeaWiFS, with a launch in the Fall of 1993, has resulted in the need for an acceleration of these tasks. Reacting to this requirement with SeaWiFS project and NOAA/NESDIS funding augmentations has resulted in providing significant progress towards achieving MODIS goals and will result in meeting the longer term milestones, if the MODIS Optical Characterization Experiment (MOCE) team survives. The SeaWiFS Project has provided approximately $2.1 million over three years to build, deploy, and operate an operational version of the prototype Marine Optical Buoy (MOBY) in Hawaii. NOAA/NESDIS has contributed approximately $500,000 towards completing/upgrading the prototype MOBY and developing the at-sea experimental infrastructure. NESDIS transferred $378,000 to C. McClain and S. Hooker (SeaWiFS Project) to augment the buoy contract with Moss Landing Marine Laboratories and to support S. Hooker in developing a shipboard satellite image acquisition/display system for our at-sea cal/val expeditions. NESDIS also has agreed to provide $60,000 for ship support to deploy the Hawaii buoy system in 1993.

The MOCE Team which is tasked to provide the core at-sea measurements for bio-optical algorithm development for MODIS and Sea WiFS is comprised of personnel from Moss Landing Marine Laboratories (MLML) under Prof. William Broenkow, San Diego State University, Center for Hydrological Optics and Remote Sensing (CHORS) under Dr. Charles Trees and myself with1.5 NESDIS technicians. Additional at-sea support to this team is being provided by Howard Gordon and Robert Evans, University of Miami, for atmospheric measurements by Ken Voss and data acquisition system software by Jim Brown. SeaWiFS Project has provided Stan Hooker to develop an integrated ship board data acquisition system. Most of this MOCE team infrastructure has been assembled during the past 16 months. It was not until May 1993 that the funding attained a sufficient level for the Team to function efficiently. Additional NESDIS support has provided loans to bridge the time gaps between MODIS funding cycles and NOAA procurement/grant cycles. This loan support has been critical to maintaining continuity and momentum. A financial summary on the expenditure of MODIS funding to date is provided in the Appendix .

The MLML temporary facilities (the earthquake destroyed their laboratory in 1990) are now utilized for most of the systems fabrication, assembly and integration. This now includes recently leased warehouse space (4,500 sq.ft.) for constructing the MOBY systems. Peter Brewer, Dir. of MBARI had previously provided space for two years at the Moss Landing Marine Operations site at no cost to this effort.

SCIENCE PROGRESS

<u>Marine Optical System and Buoy Development</u> - In order estimate gross productivity fields, the MOCE Team is placing a major emphasis on advancing the potential for determining the concentrations of viable phytoplankton pigment concentrations i.e. Chlorophyll *a*. Assays of global ocean carbon fixation will also require us to resolve the bias introduced by the phytoplankton's physiological state at full light levels. This bias condition is inherent within the data bases acquired by orbiting visible region remote sensors due to their observational constraints. The potential errors associated with this bias is important when time dependent productivity fields are generated from the satellite derived "instantaneous fields." Realizing this goal will require a deconvolution of the spectral water-leaving radiances, which will exclude the optically significant contributions from matter which are not directly linked to the photosynthetic process. If this effort is successful, it will represent a significant advancement in our ability to further quantify the "bio-optical state."

However, the effective application of Ocean Color satellite observations to produce any products relies on retrieving accurate and precise water-leaving radiances. Thus, central to this Team's approach is the success of the new marine optical instrumentation and buoy systems being developed for the field expeditions.

The NESDIS prototype Marine Optical System (MOS) is presently being tested and refined. The system uses a modular design concept to provide a generic system with intrinsic flexibility. The concept is constrained by the buoy requirement that the instrument be capable of maintaining measurement integrity while being unattended for long periods of time. This constraint has lead to a design which minimizes the number of moving parts (one) and has resulted in the spectrographic application of concave holographic diffraction gratings. These spectrograph gratings approximate a flat focal field to the degree that planar silicone photodiode arrays may be used as detectors. Inherent within this technology are the features of simplicity, compactness, durability, and stable high performance system characteristics.

The system must also be capable of measuring radiometric properties with high spectral resolution and stray light rejection. Spurious flux due to internal scattering within the monochromator is a major problem in acquiring spectroradiometric measurements within the sea. Water produces a large range of monochromatic radiant energy levels due to the high attenuation of radiant energy within the longer wavelength portion of the visible spectrum. The range of the energy levels occur at the exit slit (plane) while the energy at the entrance slit remains constant. This range for downwelled spectral irradiance increases with depth and will vary over 3-4 decades near the surface and over 8 decades at fifty meters. The higher ranges present problems for the double monochromator systems with stray light rejection on the orders of 10^{-7} to 10^{-8}. Since the holographic grating design for linear arrays does not permit a double-pass configuration, the approach employed for this dual spectrograph system will utilize a dichroic mirror "water mirror" (forty-five degree incident angle). This dichroic mirror is designed to transmit the red(630 to 900 nm) and reflect the blue portions (380 to 600 nm) of the spectrum, making the transition from reflectance to transmittance between 600 and 640 nm (beginning of the water attenuation). Corion Inc. successfully completed the design and manufacture of this "water mirror". Initial tests of the mirrors indicate an average reflectance of 98.7% between 350 to 600 nm and and average transmittance of 90% between 630 to 900 nm (Fig.1). The potential for stray light is greatly reduce by splitting the visible spectrum at the beginning of the water absorption region since most of the short wavelength energy is diverted from the entrance slit of the long wavelength spectrograph. The splitting also allows the spectrographs (gratings and sampling periods) to be optimized for the two distinctive spectral domains. A further reduction of stray light for the long wave spectrograph will be achieved by utilizing a minus blue filter. The conceptual optical schematic illustrating the primary components are shown in Figure 2. This approach is unique to marine optical applications and is proving to be an elegant design for the measurement of the apparent optical properties in the marine environment.

An overview of the salient features of this system development effort are listed below:

Marine Optical Instrument and Buoy System Features

- <u>Optical System</u>
    - Optical
        - Dual Spectrographs

- Dichroic Beam Splitter
  - Reflected 380-600 nm
  - Transmitted 630-900 nm
- Concave Holographic Gratings
  - Flat Field
  - #1 Range 350-650 nm Blazed @ 440 nm
  - #2 Range 600-900 nm Blazed @ 700 nm
- Linear Array Detectors
  - 512 element silicon photodiode
  - Thermoelectric Coolers

- Collectors
  - SIO VISLAB-Vector Irradiance
  - Telescopes - Radiance
  - Fiberoptic Mutiplexer
    - Ten Remote Collectors

- <u>Ancillary</u>
  - Pressure
  - Temperature
  - Magnetic Heading
  - Inclination (two-axis)

- <u>Data Acquisition</u>
  - Direct (9600 baud)
  - Telemetry (GOES)
  - Telemetry (ARGOS)
  - Cellular Telephone

- <u>Data Acquisition Software</u>
  - DEC/VMS & MS/DOS

- <u>Data Reduction & Analysis Software</u>
  - DEC/VMS

- <u>Deployment</u>
  - Ship
  - Moored Buoys

- <u>Satellite Positioning</u>
  - Global Positioning System
  - Argos

- <u>Data Archive</u>
  - Near-real time & historical
  - Phone Access

The marine optical system has been integrated and deployed on a slack-line moored, solar powered, spherical buoy which is attached to a twelve meter "optical bench" (Fig. 3). The buoy is a modified Coastal Climate Corp. MINIMET buoy which is one meter in diameter with three 40-watt solar panels mounted to the antenna support column. The surface buoy houses computers, 12v power supply, satellite data transmitting unit and mass storage (Fig.4). The optical system and battery packs are mounted subsurface within an instrument bay at the bottom of the "bench" (Fig.5). Apparent optical properties (upwelled radiances and downwelled irradiances) are measured by a series of remote collectors, at three depths, along the column. The remote collectors are coupled to the instrument through a fiberoptic multiplexer which is a rotary selector with relay optics coupled to one of the view/entrance windows. The optical and ancillary data will be compressed, stored and forwarded through a cellular telephone or GOES telemetry link via a Sutron 9000 DCP. A series of photographs in Figures 6 and 7 depict the system in various stages of construction at the MBARI facilities.

This prototype marine optical buoy system is now complete. Individual system component testing and the initial buoy mooring test were successfully completed by June 1991. A test deployment of the buoy with no instrumentation was successfully completed in August 1991 and the fiber optic system tests were completed in October 1991. The complete buoy system integration and deployment were successfully completed in October 1992. The shallow water mooring configuration used in the initial test is illustrated in Figure 8. This initial test demonstrated that the system concept is valid. The only unanticipated event was water seepage in the new right-angle fiber optic collection heads which negated the recovery of any calibrated radiance data. Although these collector heads passed the high pressure tests the o-ring grooves were five thousandths out of specification which proved critical in the low pressure (shallow depths) application. A sample of the transmitted downwelled spectral irradiance data (least affected by the moisture) are illustrated in Figures 9 (surface), 10 (mid depth), and 11 (bottom). The only other major annoyance (anticipated) was with the extremely slow microprocessor in the GOES DCP (Sutron 9000) which is being replaced by a central controller on future systems and will serve only in GOES data transmission and power controller functions.

The construction of the SeaWiFS Hawaii system began May 1992. This system is to be operational by September 1993, prior to the SeaWiFS launch. This operational system has many system modifications (detectors, spectrographs, cooling system, data acquisition/control computer, power supplies, and increased reserve buoyancy in the buoy) which will provide an enhance performance over the prototype system. The instrument modifications are shown schematically in Figure 12 and for comparison purposes the prototype is illustrated in Figure 13. A conceptual drawing of the modified buoy configuration is depicted in Figure 14. The major improvement to the optical system is in the replacement of the Hamamatsu PCD's with Photometics CCD detectors (Tektronix scientific grade TK512, thinned, backside illuminated,and AR coated) with three stage thermoelectric water coolers. The prototype microcontroller processors are being replaced with TT Model 7 MCU's with MLML FORTH operating systems. These low power consumptions Model 7's provide 32 bit, 16 Mhz computing speed, timing functions, real-time clocks, and 80 MB disk storage.

SeaWiFS Calibration/Validation Site - The two candidate sites for MOBY deployments are the JGOFS time-series stations at Bermuda and Hawaii. Although, these locations are not the ideal for optimizing the satellite cal/val requirements the logistics and frequency of bio-optical observations being collected at these sites were a deciding factor. The Hawaii site has been selected for the initial deployment since it has less cloud cover. However, I have decided not to do the initial mooring at the JGOFS - HOTS location. This change in location is based primarly on survivability considerations and the high data interrogation rate provide by the GTE Mobilnet cellular telephone service. The location of the mooring, west of Lanai in the lee provided by the three Islands of Molokai, Maui, and Lanai, is designated in Figure 15 by the cross hatched area. Also depicted in Figure 15 are the 30 yr. mean wind speeds isopleths and the GTE Mobilnet sites with their effective 45 nm marine communication ranges. With such a complex system, which has not been tested in open ocean conditions for a long time period, it is prudent to reduce the surface moorings' exposure to the constant beating from the trade winds,. Another, consideration which could prove beneficial to the SeaWiFS and MODIS atmospheric correction efforts, for correcting for sea state (white caps & foam), is that this site has fully develop seas with 20 kts. of wind on the windward side of the islands to near mill pond conditions on the leeward side providing an ideal test site for algorithm development and testing.

The software and hardware are presently under development for the deep ocean mooring (Fig. 16) and for the acquisition system to capture and process the transmitted data from MOBY. These data must be converted into calibrated radiances and a water-leaving radiance data base transferred to SeaWiFS Calibration Team for sensor quality control monitoring and algorithm development. A conceptual data processing scheme is shown in Figure 17. This system when operational will serve as a prototype for the MOTCF. A sample of the transmitted MOBY ancillary data for one observational sequence are listed in Table 1.

Preliminary SeaWiFS & MODIS Bio-Optical Algorithm Development - This element presently relies totally on the CZCS bio-optical data base which has been recast for the SeaWiFS, MODIS- N, and MODIS-T spectral channels. The water-leaving spectral radiances were first normalized to be consistent with the procedures describe by Gordon et.al. Applied Optics, 1983 and then convolved with the CZCS 520nm band pass characteristics (Ball 1979) for the wavelength regions and bandwidths anticipated for these sensors. The pigment data have had an optically dependent weighting function applied to their vertical distributions. It is obvious that the vertical distributions of C should be weighted by a function which takes into consideration that material near the surface is optically more important than that at greater depths. The function was found by noting the exponential attenuation of irradiance with depth and assuming that the backscattered energy would be approximately attenuated in the same manner on its return to the surface. Thus a layer of pigment/matter at depth Z will have its optical contribution reduced by the factor $e^{-2K_E Z}$, compared to a similar layer at the surface. Hence, the vertical distribution of pigments are weighted spectrally with the function $f(z)=e^{-2K_E Z}$. This procedure has been evaluated theoretically by Gordon and Clark Applied Optics(1980) and shown that the optically weigthing provides an accurate representation of the pigment concentration as observed by a remote sensor viewing a stratified ocean.

These normalized water-leaving radiances were formed into ratios and related empirically to the sum of the optically weighted photosynthetically active phytoplankton pigment chlorophyll *a* and phaeopigment *a*, (Chl *a*'s associated degradation product). Examples of these analyses are illustrated in Figures18 and 19.

Initial results have demonstrated that the base line in-water relationships will not differ significantly from the CZCS types of accuracies. I have small errors in the new data based and they are being corrected. The corrected data fields for the sensors will be recomputed once the final SeaWiFS spectral system responses are provided by SeaWiFS Project (Feb.1993).

<u>MODIS- Marine Optical Characterization Experiment Team Campaigns</u> - The first field deployment involving the core personnel of this team was conducted at the Moss Landing Harbor during October 1991. The objectives were primarily to test new instrumentation, develop measurement protocols and begin to characterize the apparent optical properties in turbid water with a focus on the NIR. This long-wave region of the spectrum is extremely difficult to obtain accurate measurements in the marine environment due to the strong absorption of water and instrument self-shading effects. The MOS with its unique fiber optic capabilities proved to be well suited for these measurements. The system was configured with the fiber optic multiplexer and suspended below a tetrahedral buoy (which is used for deploying radiometers away from ships to avoid shadows). A miniaturized cosine collector for downwelled irradiance and a bare fiber with and FOV of 13 degrees for upwelled radiance were mounted to a support bracket with the fiber optic cables running to the subsurface multiplexer. The supporting bracket was attached to a winch located on the buoy which would raise and lower the collectors to the desired depths. Typical observational depths were between 2 mm and 70 mm. The upwelled radiance counts for the 18 and 48 mm depths are plotted in Figure 20. In order to reduce capillary wave noise the buoy was encircled with wave damping floats used for swimming racing lanes. Photographs in Figure 21 illustrate this measurement approach. Incident irradiance was also measured using GFO radiance collector fitted with a miniature acrylic cosine collector which mounted to the top of the buoy with a fiber optic relay to the MOS. Water samples were collected at the various depths with a submersible pump and small tygon tube attached to the optical mounting bracket. Also, during this experiment a new spectrophotometric system and a pure water production system for measuring the absorption of colored dissolved organic matter and particulate matter in sea water was successfully tested. This system will be incorporated into the suite of at-sea bio-optical measurements for future Ocean Color experiments.

The MOS, with its fiber optic collection subsystem along with a new capillary wave dampening system, provided excellent data. The results yielded the first observations of the spectral diffuse attenuation (380 nm to 870 nm) in highly turbid waters (Fig. 22) with minimum contamination due to instrument self-shading.

The first at-sea MOCE team deployment was conducted in the Monterey Bay and offshore waters during September and October 1992. The USN provided their RV DeSteiguer at no cost to the project. The operational schedule and participants are detailed in Figure 23.

This cruise represents a major milestone for the team, since it was the first time the diverse set of instrumentation and measurements were implemented under typical marine conditions. This was the first deployment of the MOS configured for the shipboard profiling mode of operation. Observations were routinely made at approximately 1.5, 6, and 12 meters. One of the station data sets are illustrated in Figure 24 along with the derived attenuation coefficients and water-leaving radiances in Figure 25. The incident irradiances were measured by a newly develop 38 channel spectrograph which will be discussed in future reports.

In cooperation with the EOS IDS- Biogenic Gas Flux Team headed by Peter Brewer (I am also a member of this team) and Frank Hoge, MODIS Team Member, a joint set of measurements was acquired concurrent with two NASA P3 overflights by Frank. The data reduction from this experiment is approximately 80% complete and will be provided to the WHOI , MOTCF, and SeaWiFS data bases after it is reviewed by the MOCE Team.

This Team made remarkable progress this year! Most of the members sustain a high level of performance while working extremely long hours for extend periods of time. Several members put in many months at 300 to 400 hours per month and a 500 hour stint during the MOCE 1 Cruise period. This level of effort cannot be sustained! Additional support personnel will be added to the Team with the MODIS funding in 1993.

DICHROIC "WATER MIRROR"

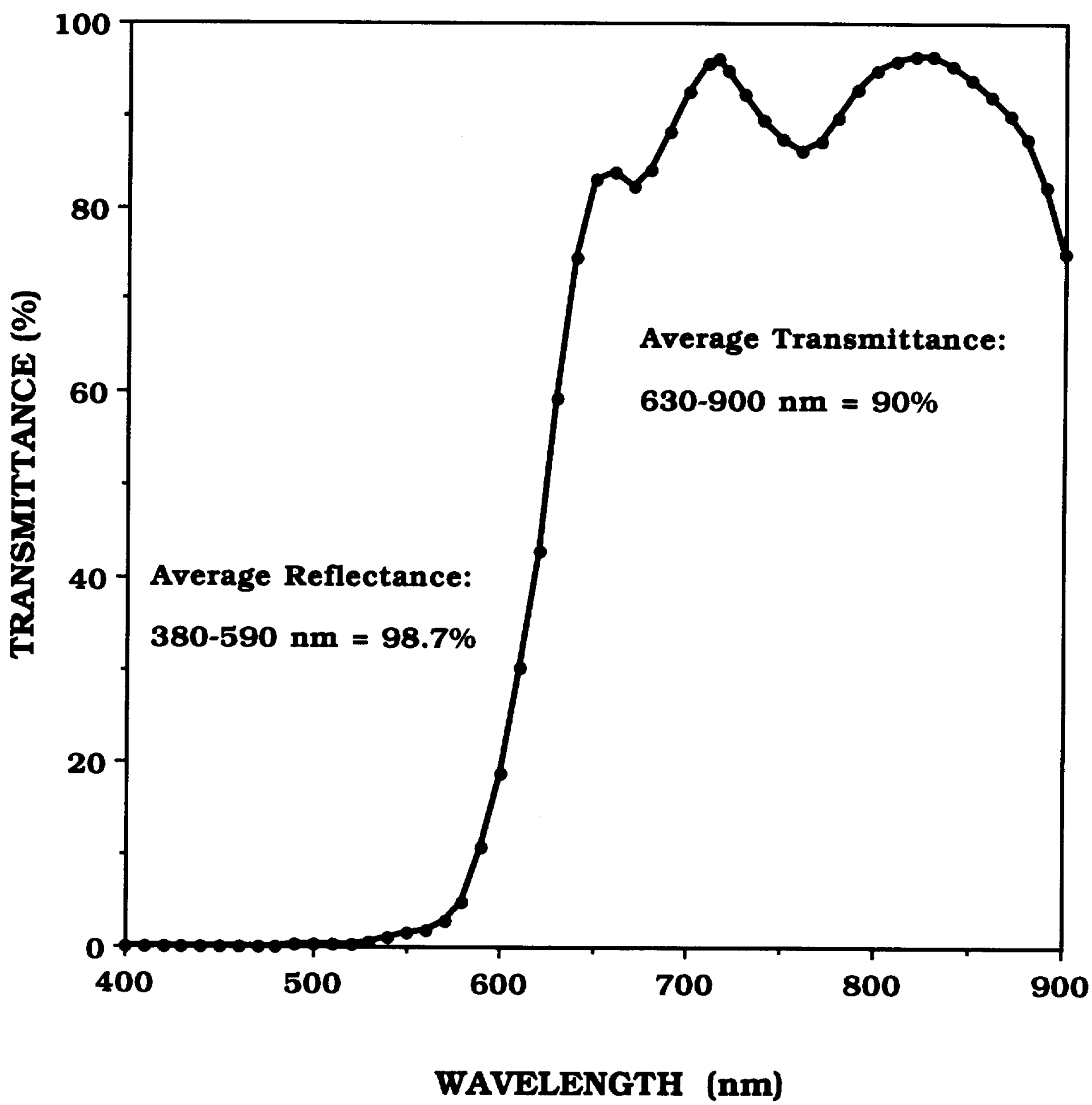


FIGURE 1

Marine Optical System - Dual Spectrographs

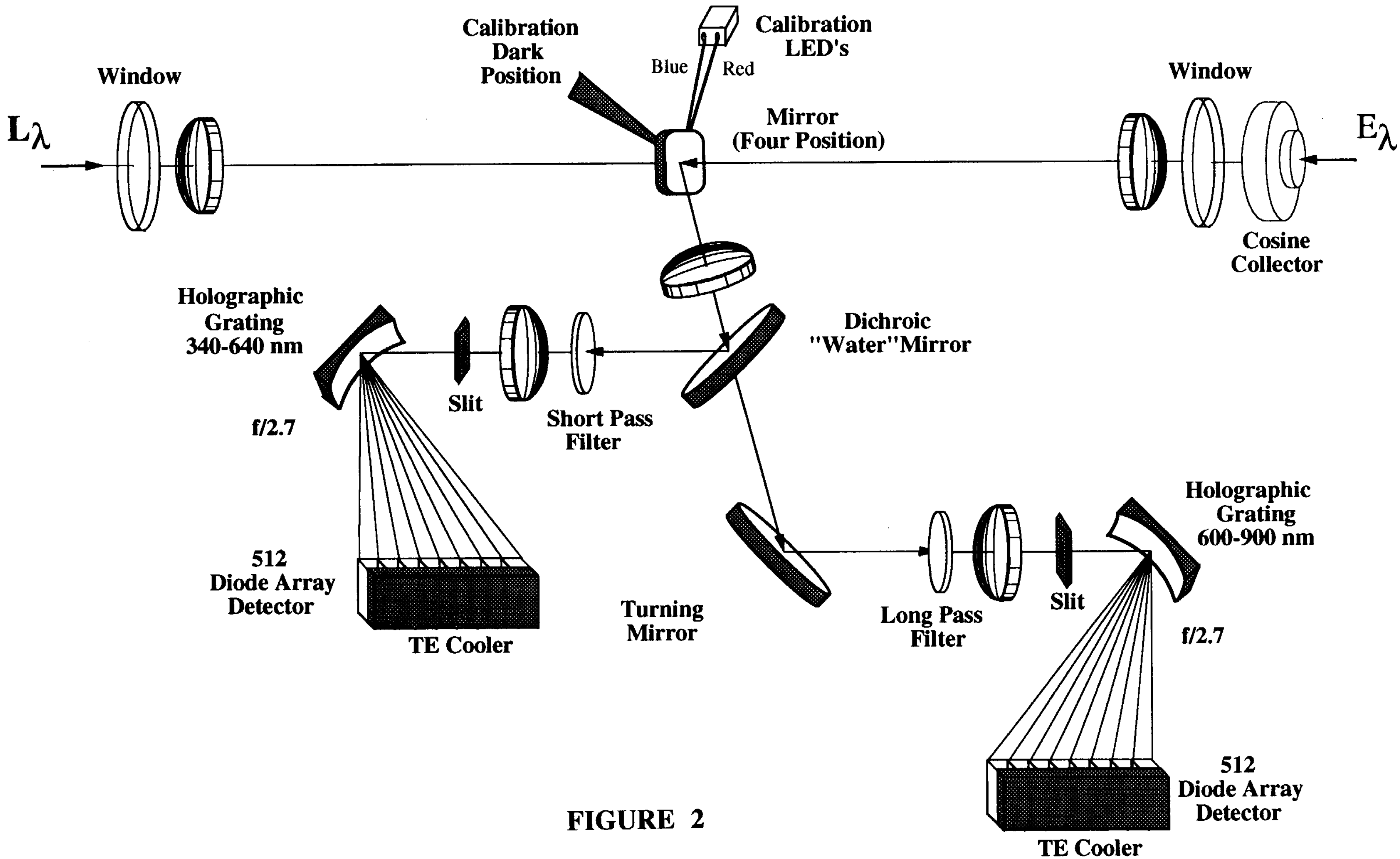


FIGURE 2

MARINE OPTICAL BUOY

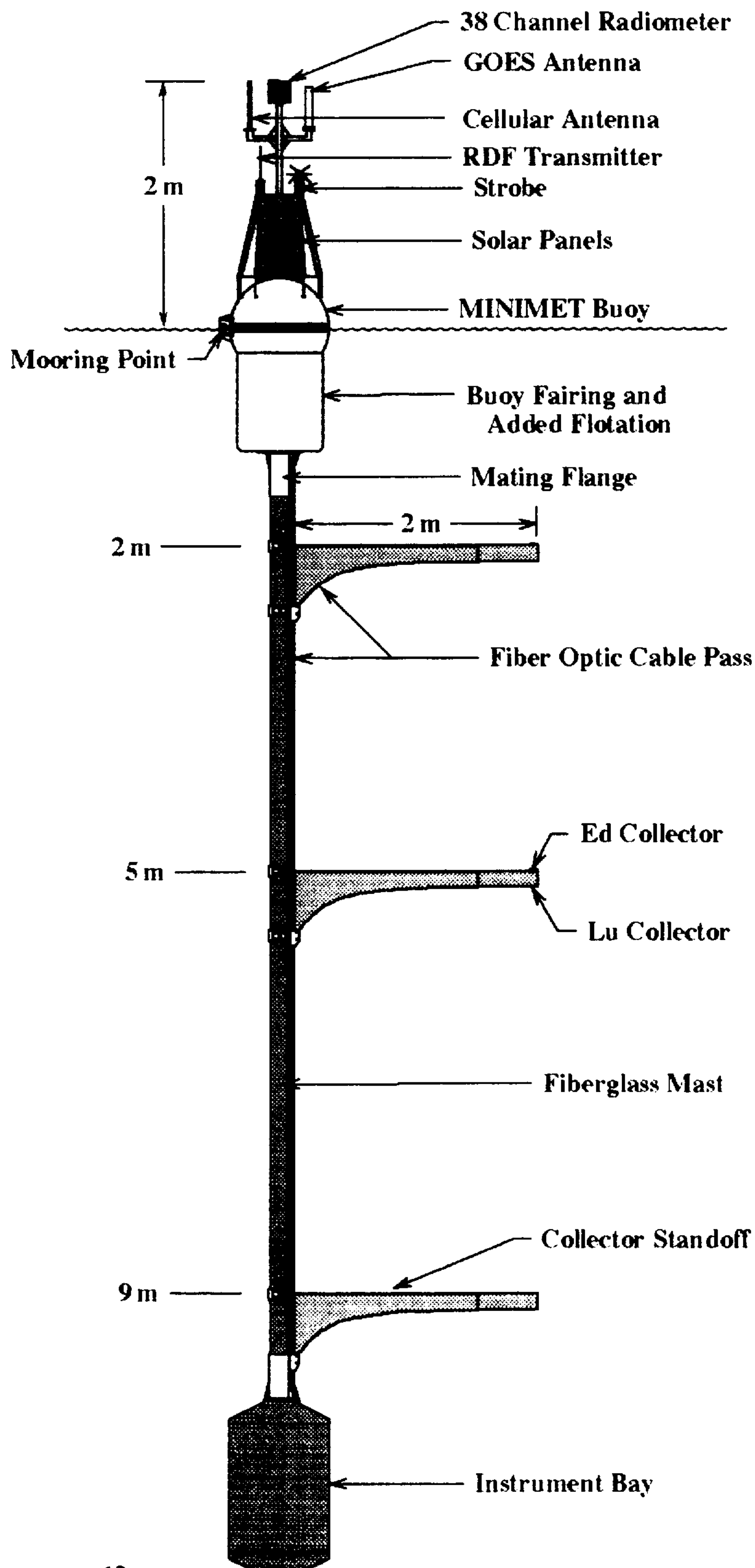


FIGURE 3

SURFACE BUOY INSTRUMENTATION

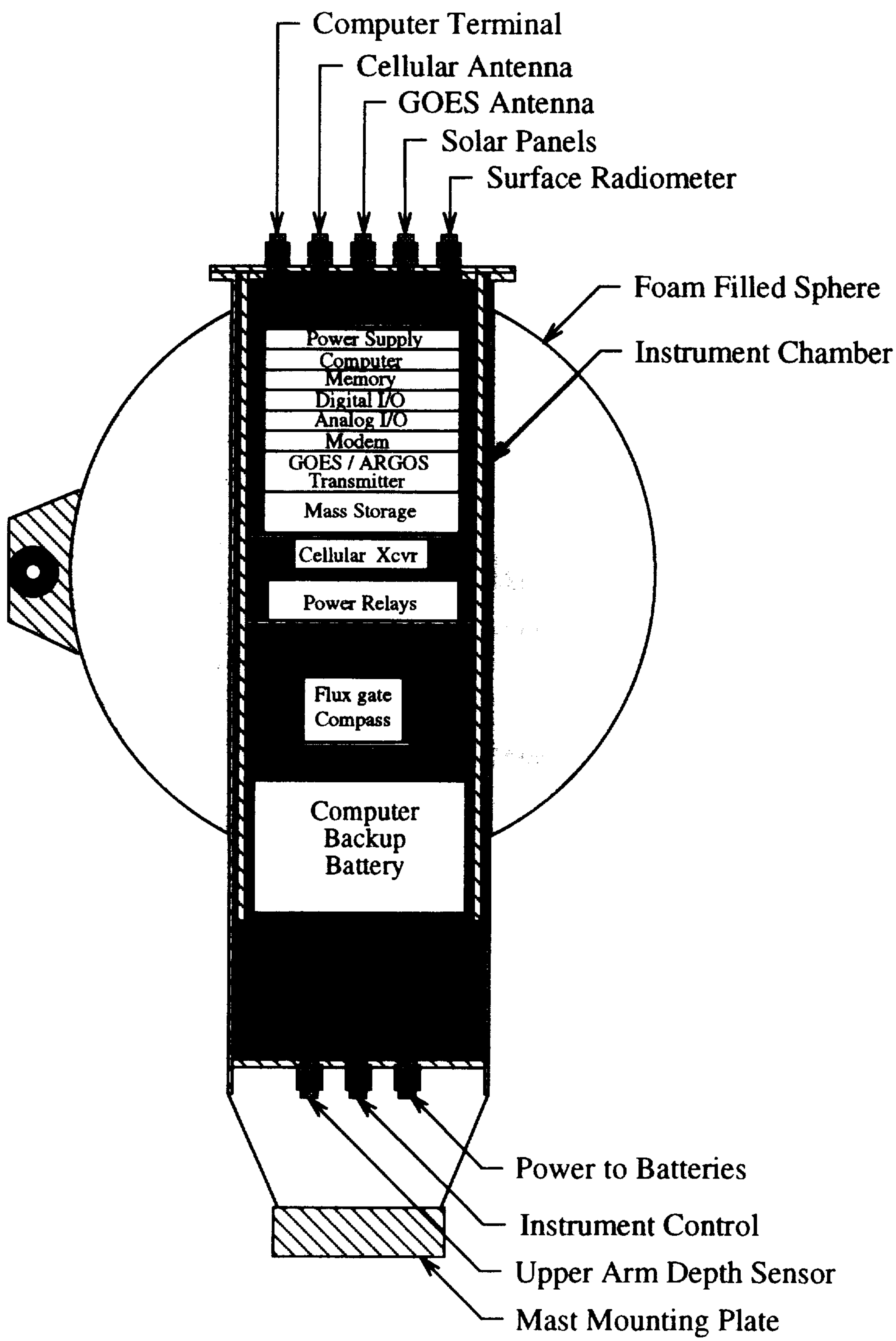


FIGURE 4

Subsurface Instrument Bay

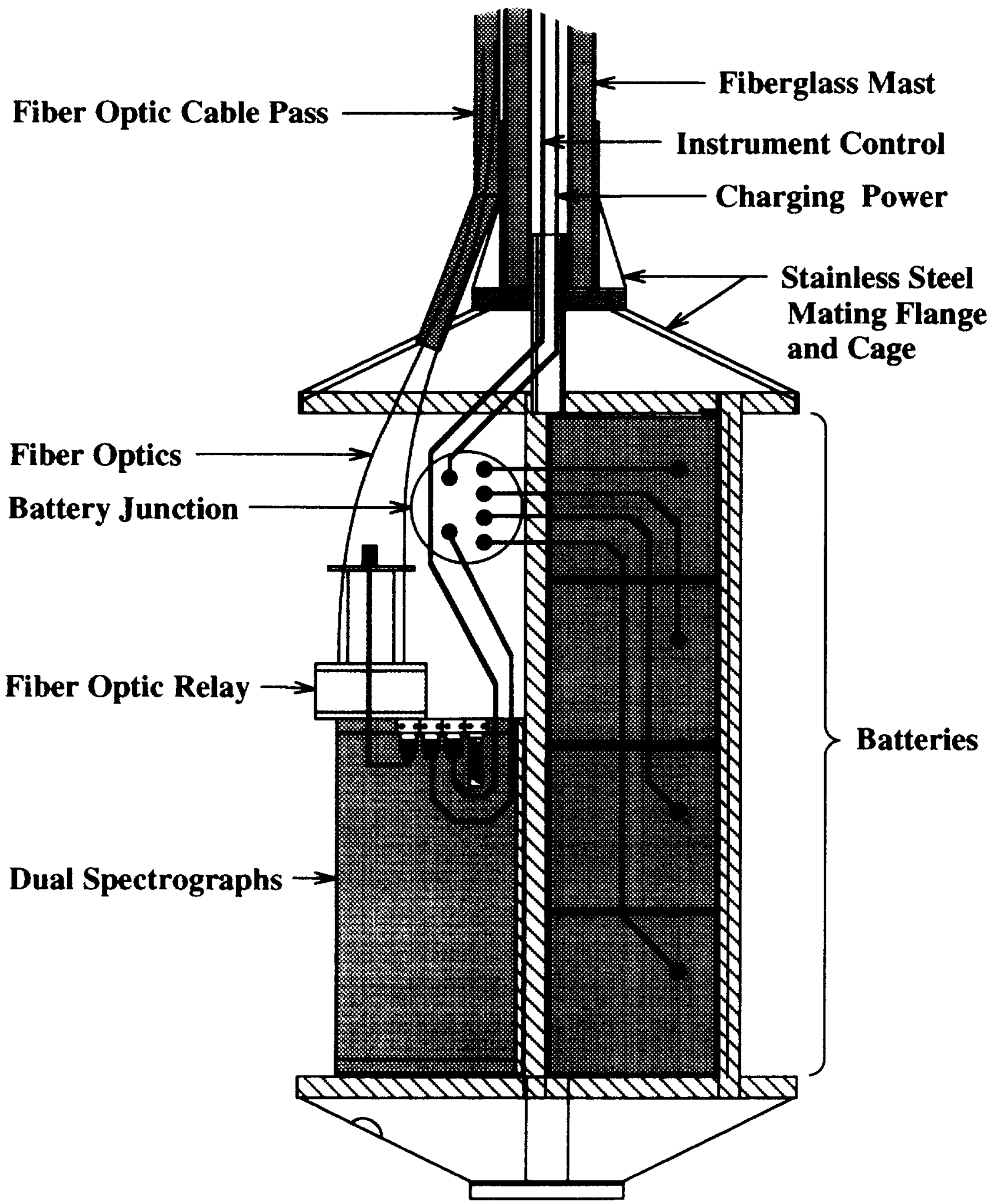


FIGURE 5

FIGURE 6 Upper Left: Outer and inner fiberglass pipe, mating flange strength rods; Upper Right: Assembled buoy and mast; Lower Left: Clamp for collector standoff; Lower Right: Collector standoff.

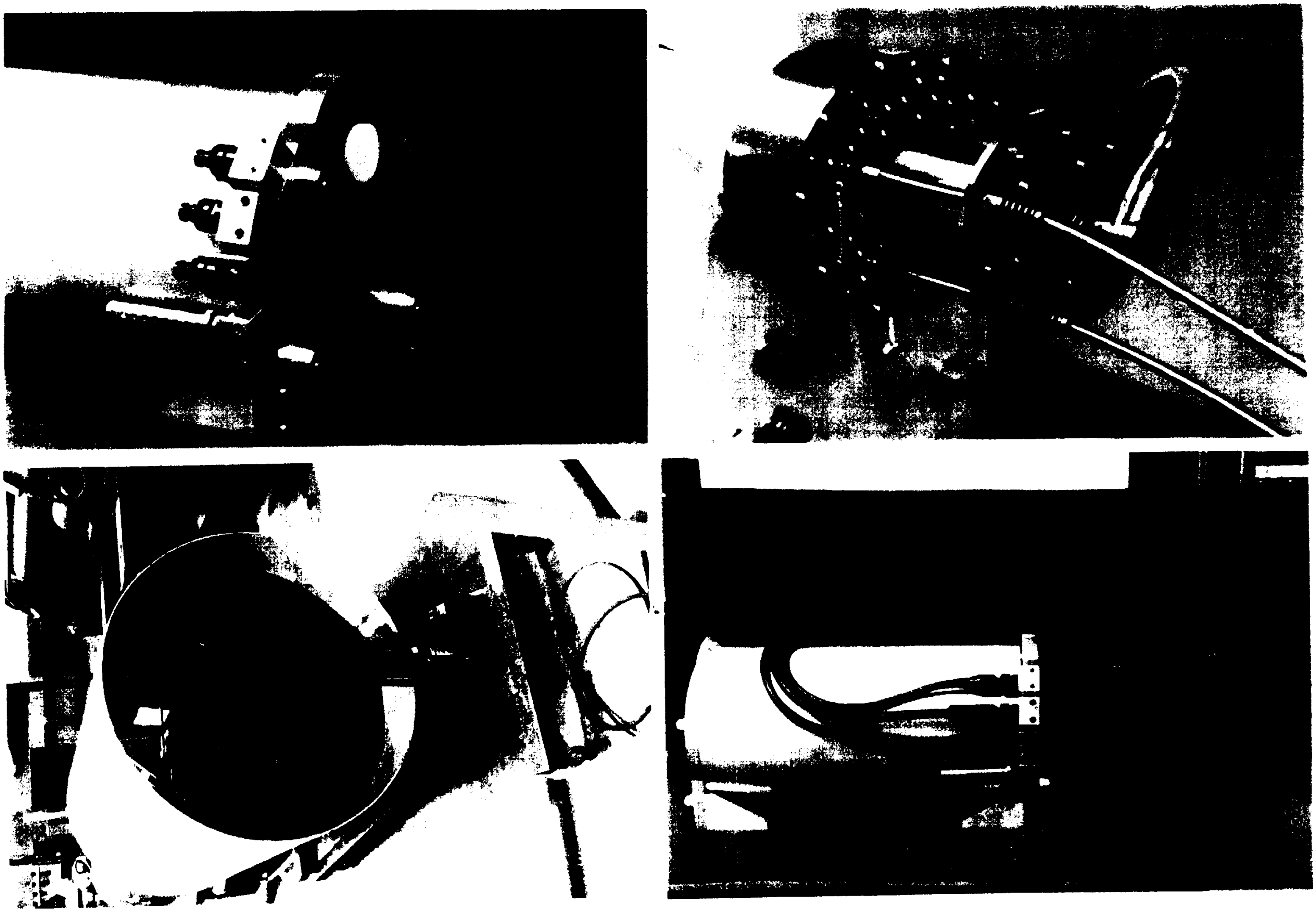


FIGURE 7 Upper Left: Submersible Radiometer with irradiance collector; Upper Right: Fiber Optic Relay. Lower Left: Instrument Bay with lower fairing removed; Lower Right: Radiometer Pressure Case.

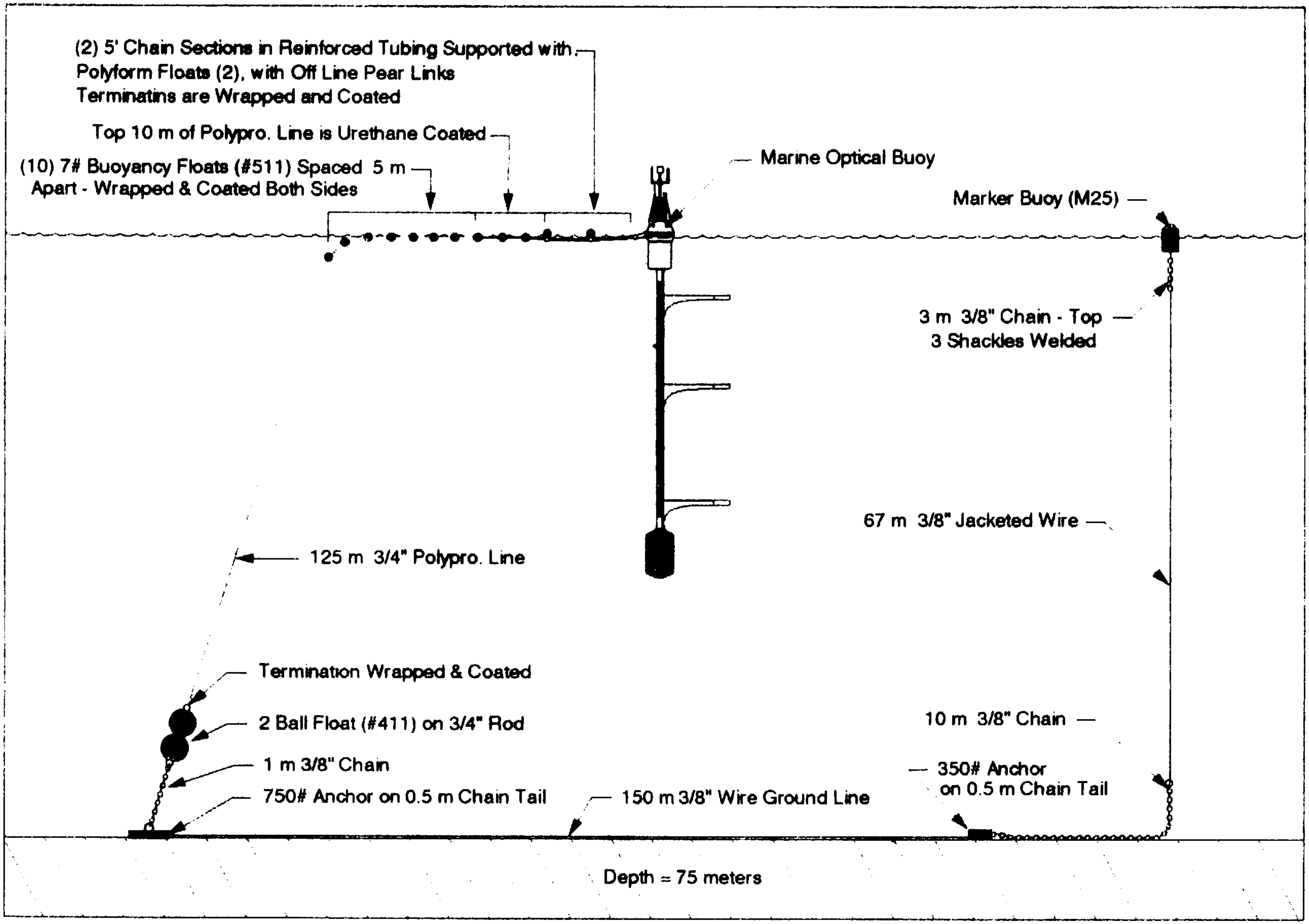


FIGURE 8 Shallow water mooring system for the Optical Buoy System. Mooring by Mooring Systems, Inc. Woods Hole, MA.

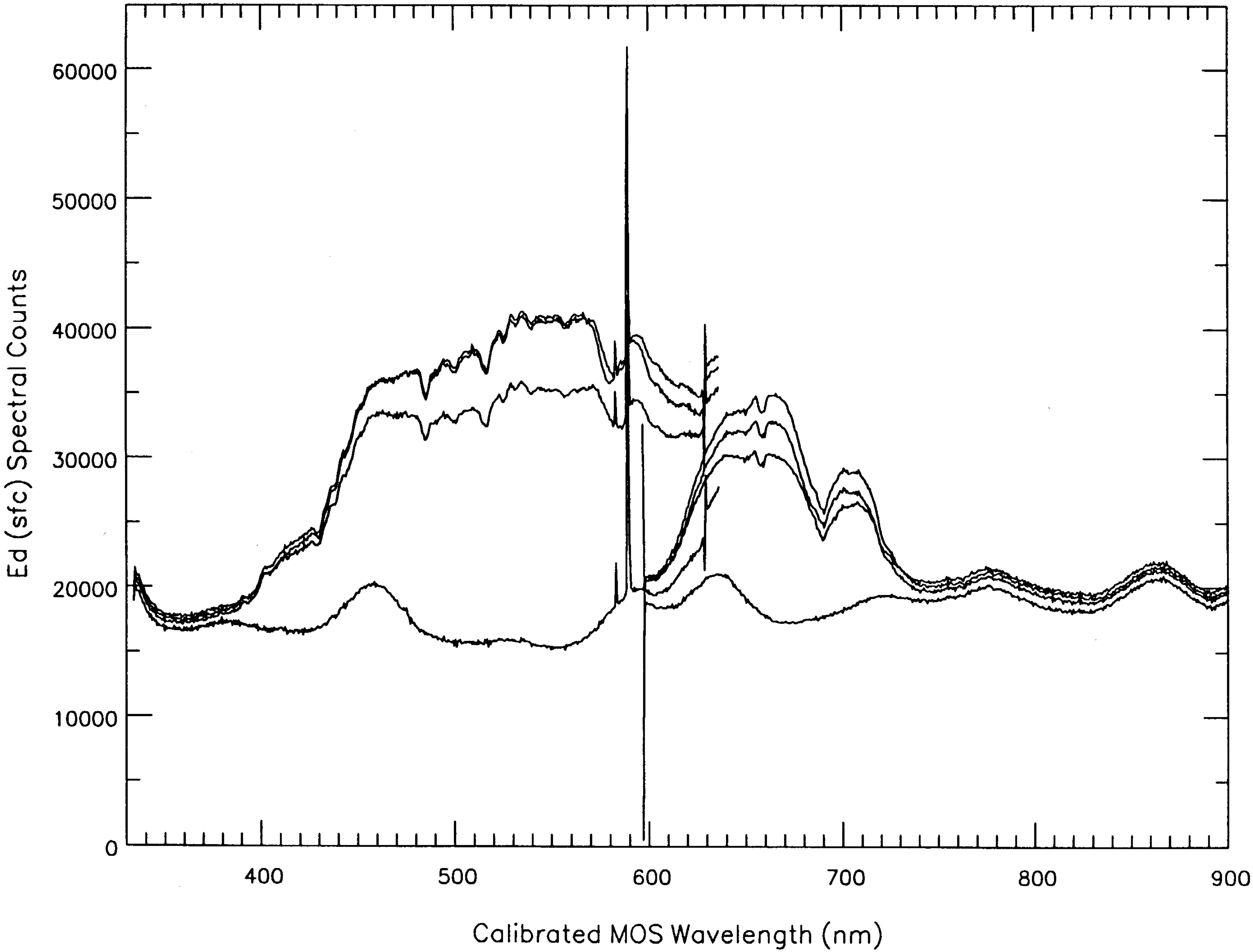


FIGURE 9

MOBY 21 Oct 92 30 Oct 92

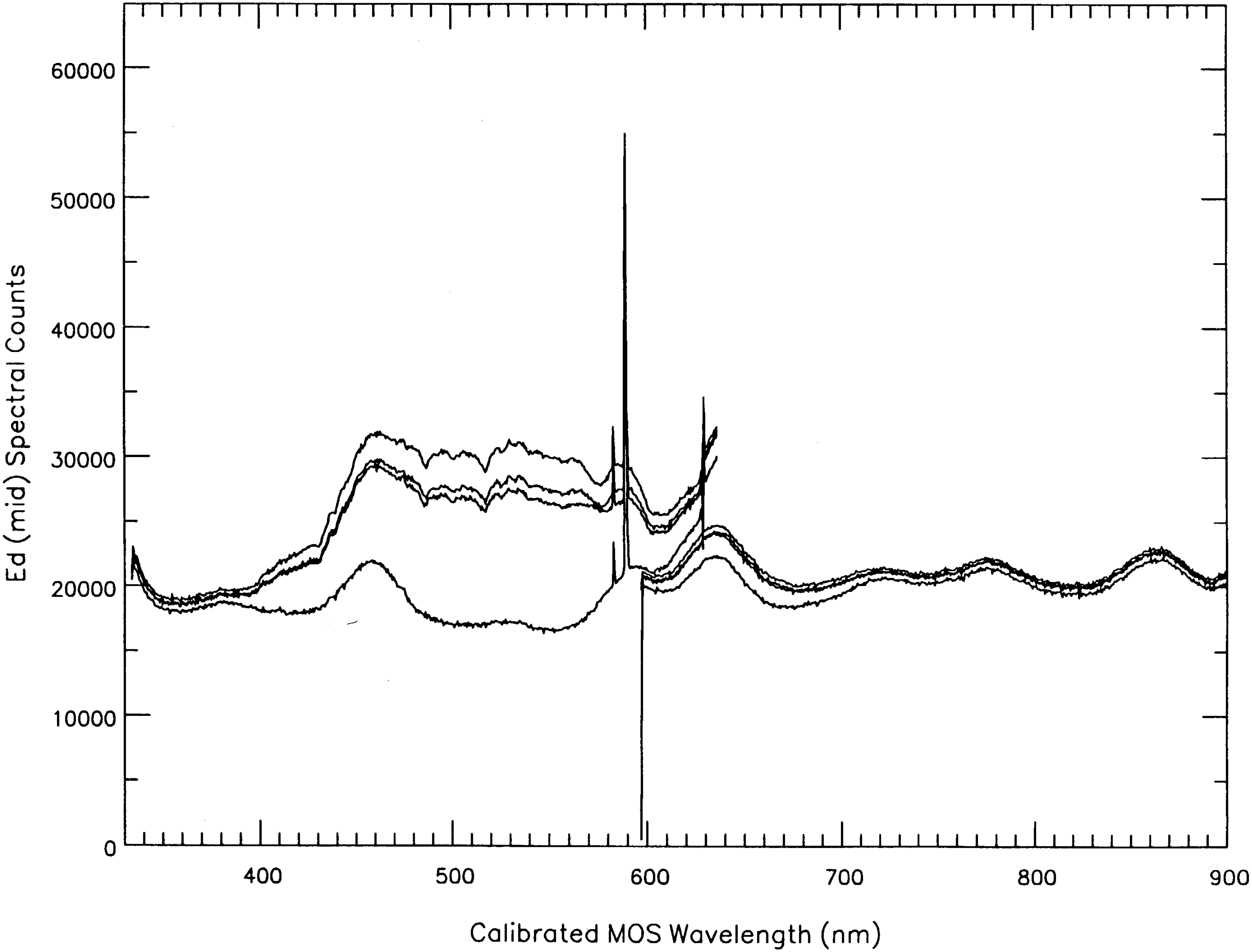


FIGURE 10

MOBY 21 Oct 92 30 Oct 92

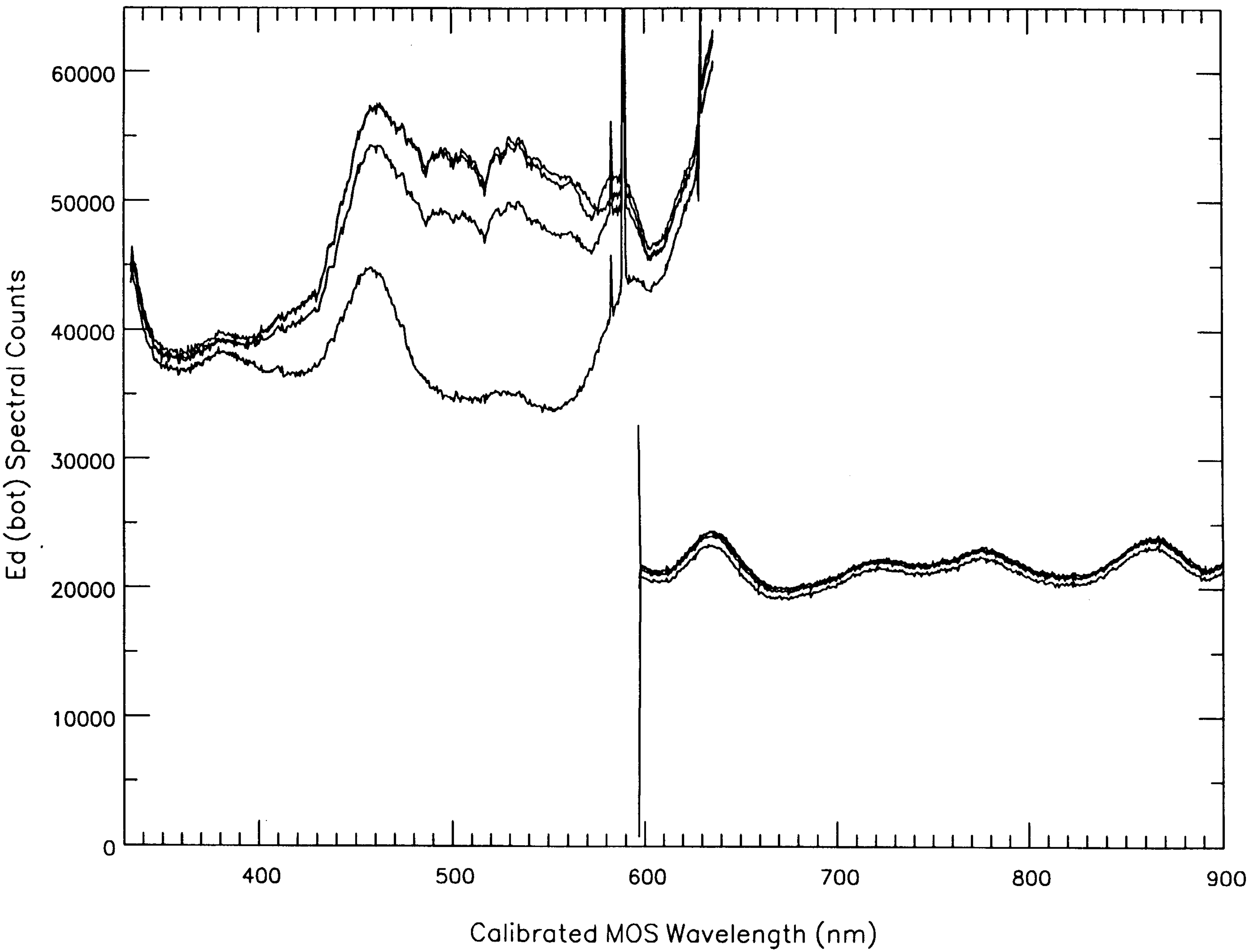


FIGURE 11

MOBY 21 Oct 92 30 Oct 92

UPGRADED MARINE OPTICAL SYSTEM - Electronics

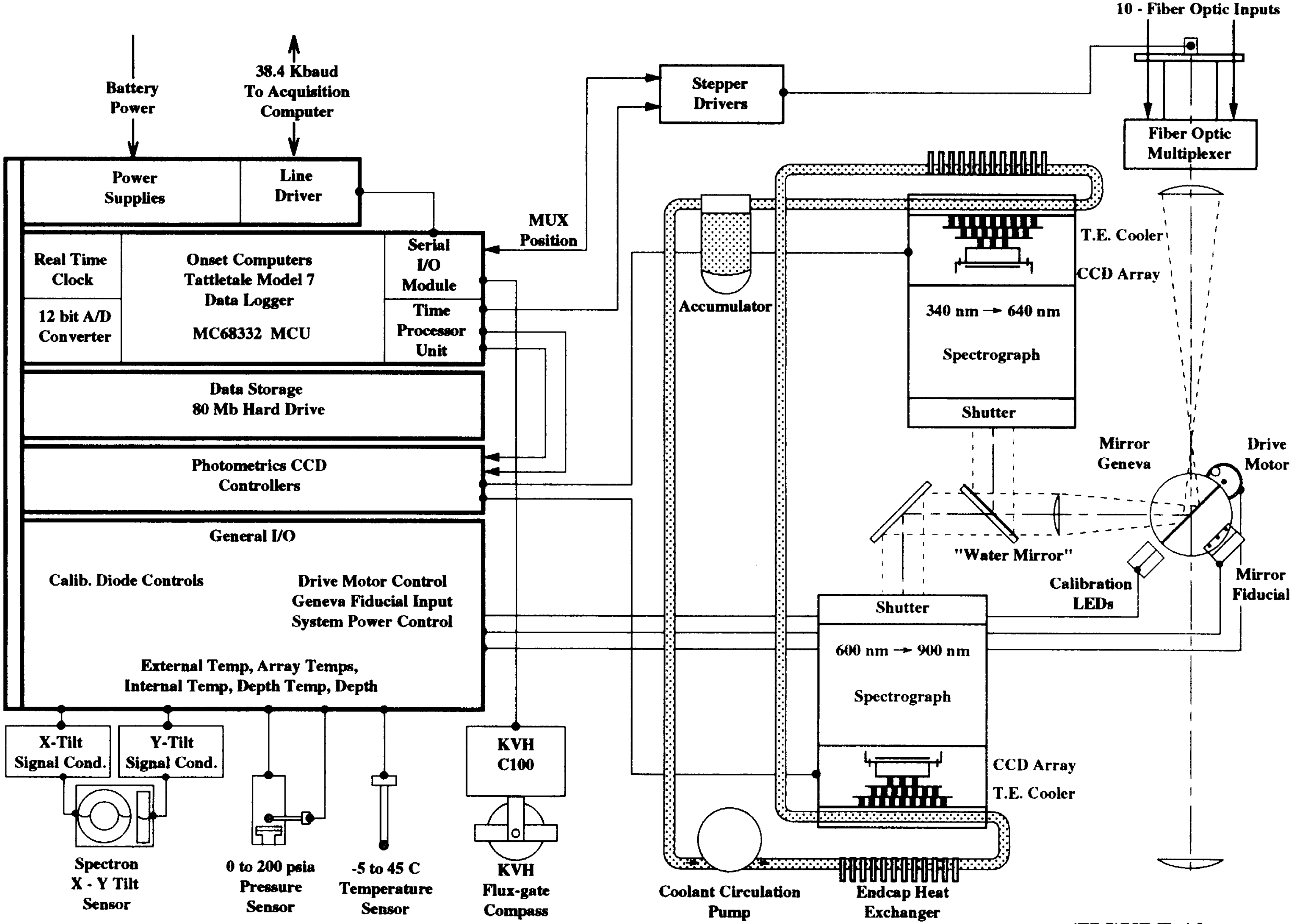


FIGURE 12

Marine Optical System - Electronics

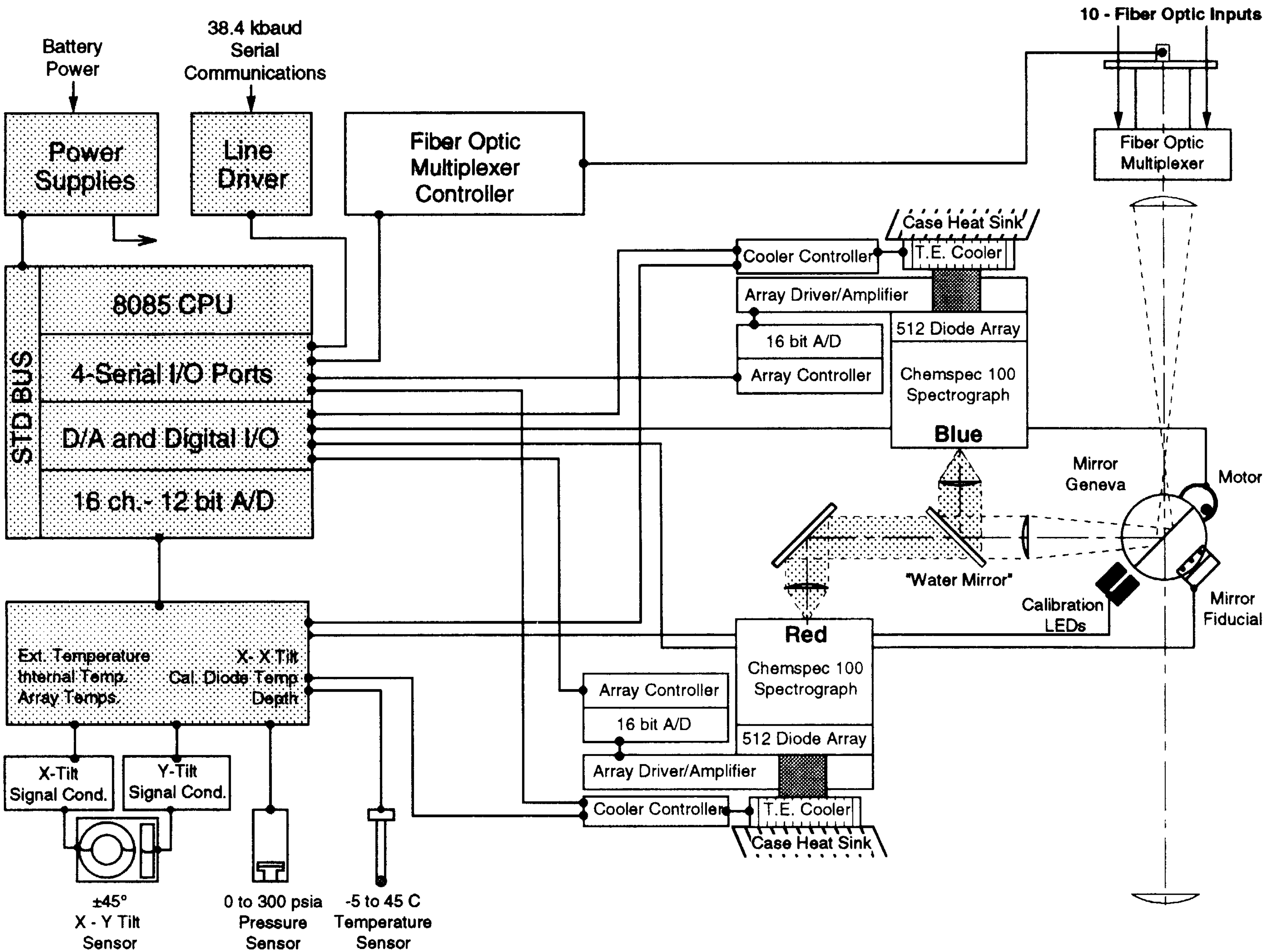


FIGURE 13

MOBY-2

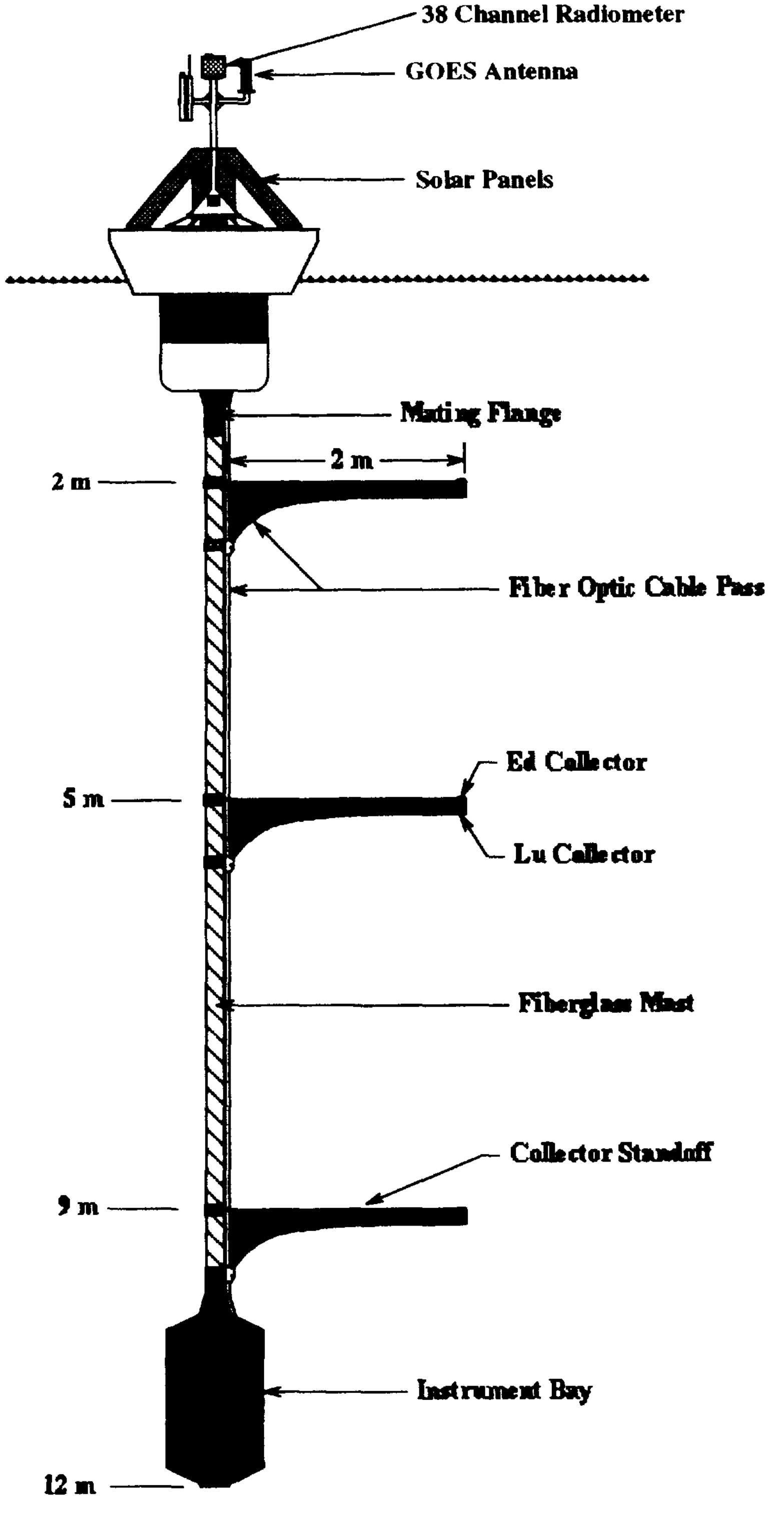


FIGURE 14

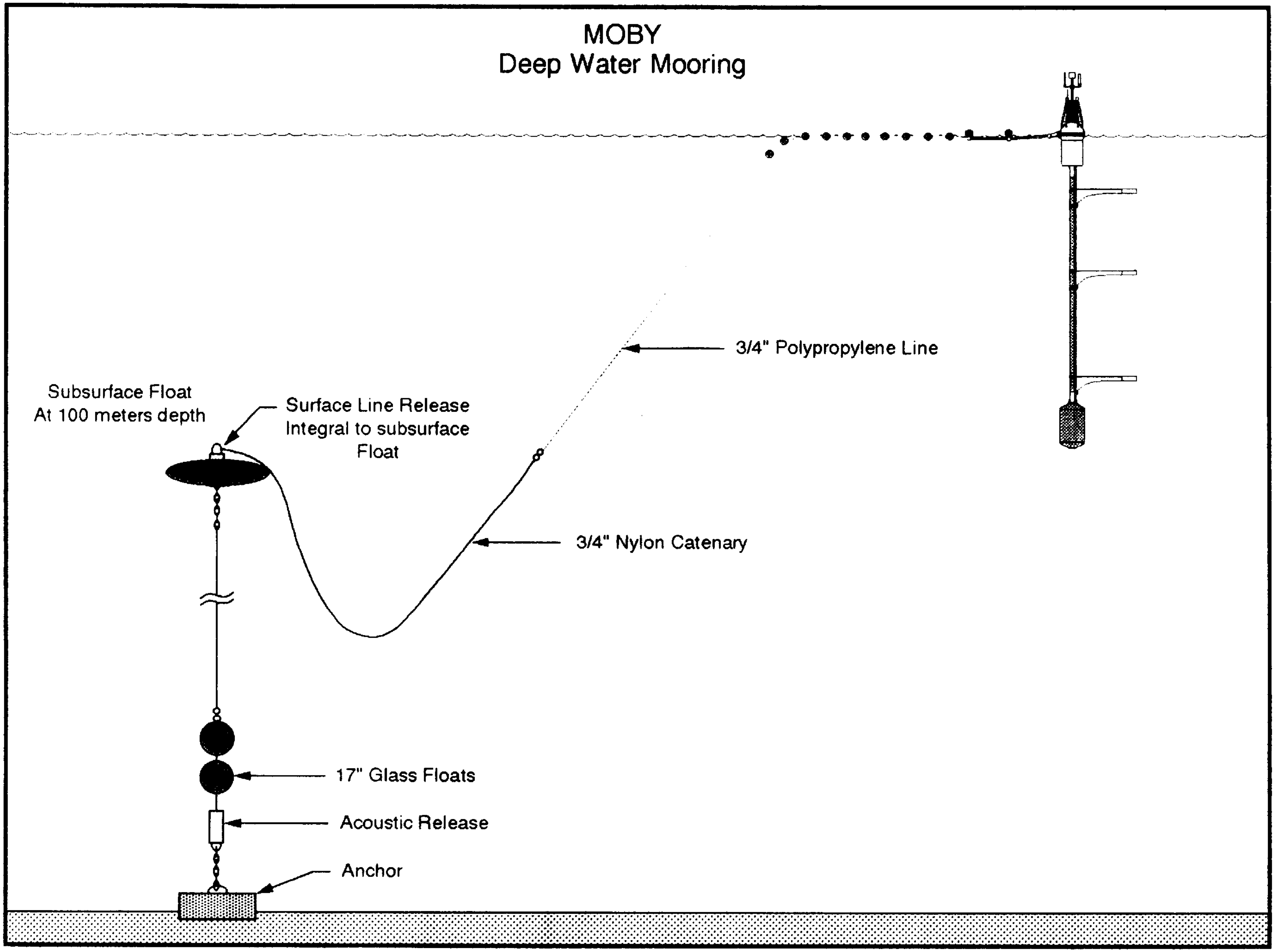
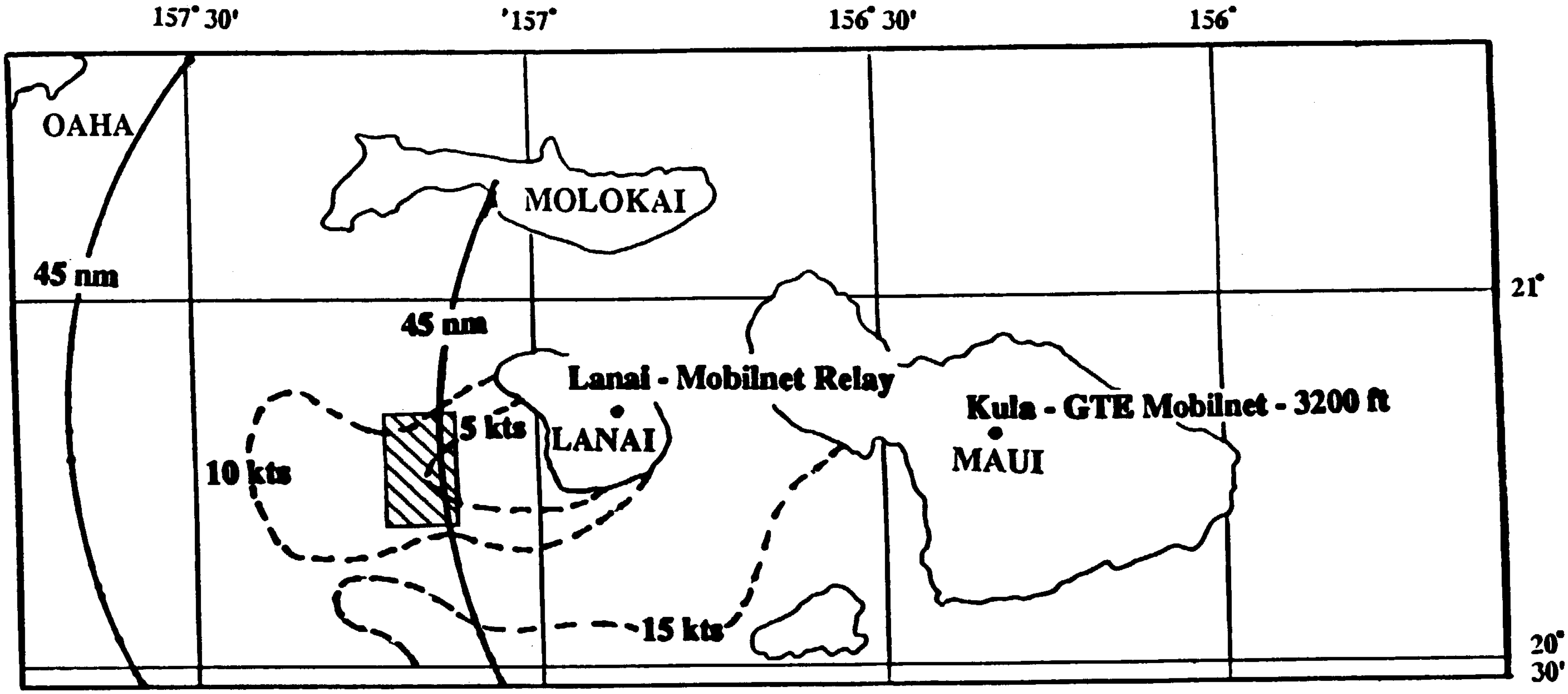

MOBY
Deep Water Mooring
3/4" Polypropylene Line
Subsurface Float
At 100 meters depth
Surface Line Release
Integral to subsurface
Float
3/4" Nylon Catenary
17" Glass Floats
Acoustic Release
Anchor

FIGURE 16



Moby 1 Deployment Site - Lanai

FIGURE 15

DATA PROCESSING

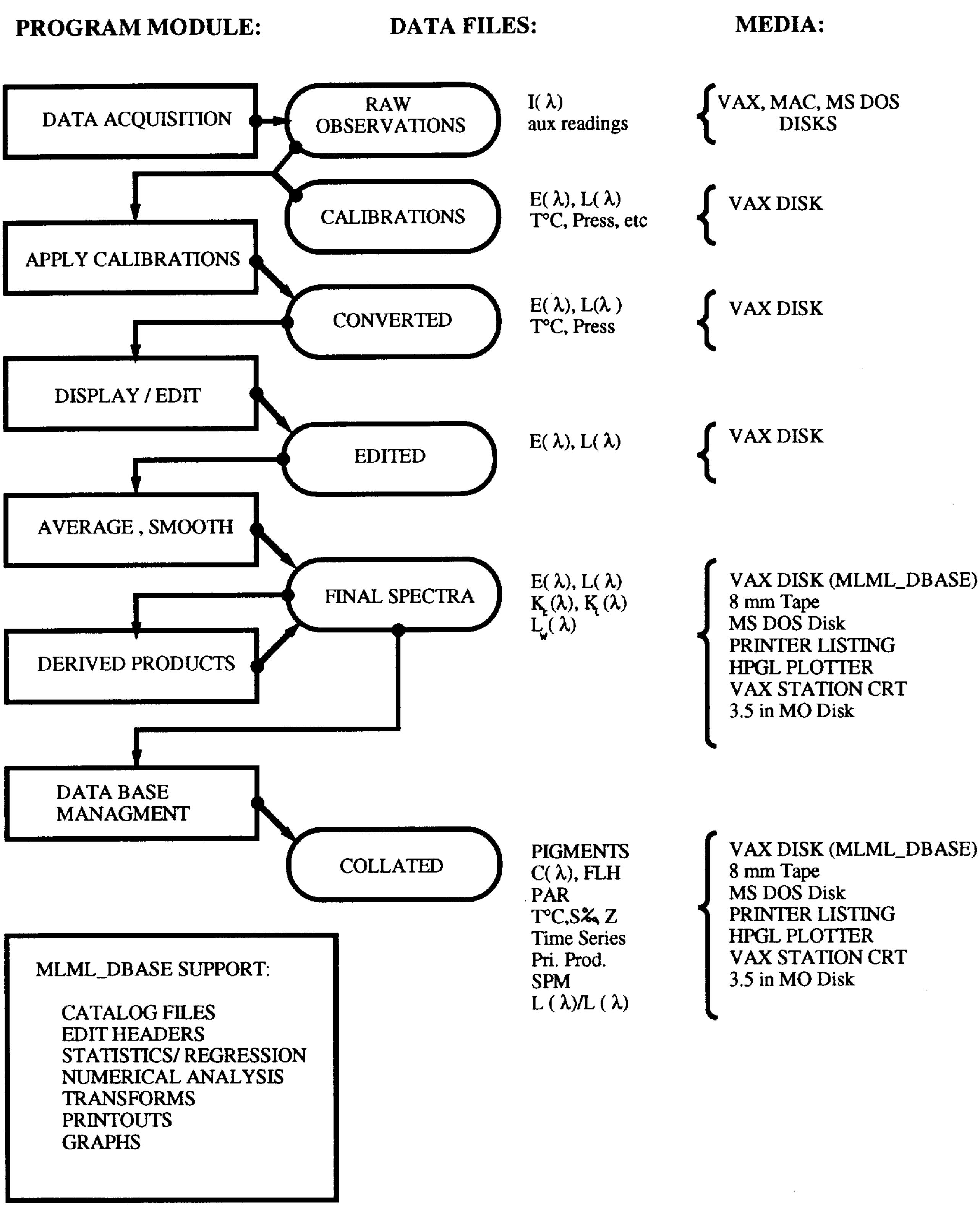


FIGURE 17

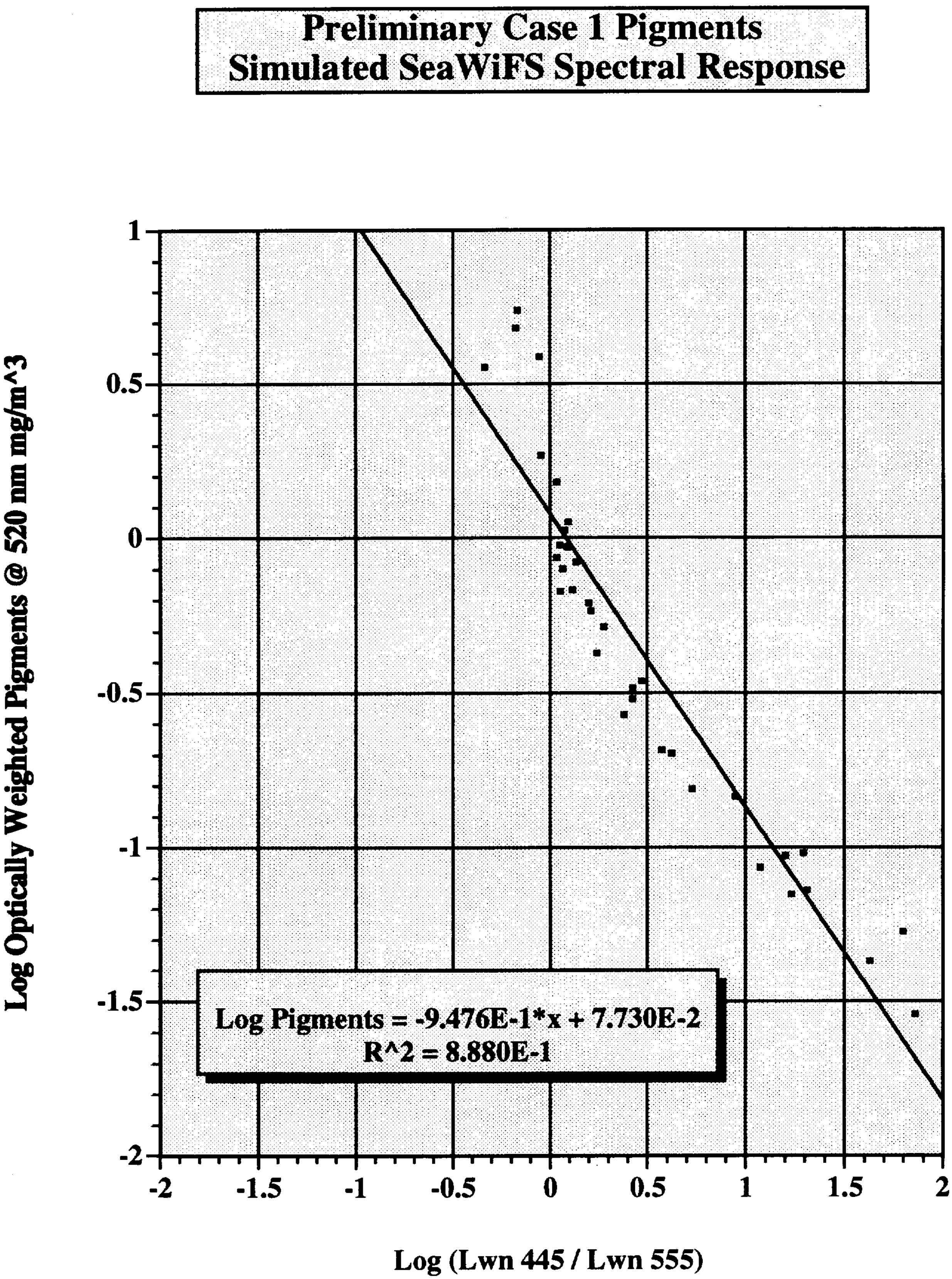

Preliminary Case 1 Pigments
Simulated SeaWiFS Spectral Response
Log Pigments = -9.476E-1*x + 7.730E-2
R^2 = 8.880E-1
Log Optically Weighted Pigments @ 520 nm mg/m^3
Log (Lwn 445 / Lwn 555)
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2

FIGURE 18

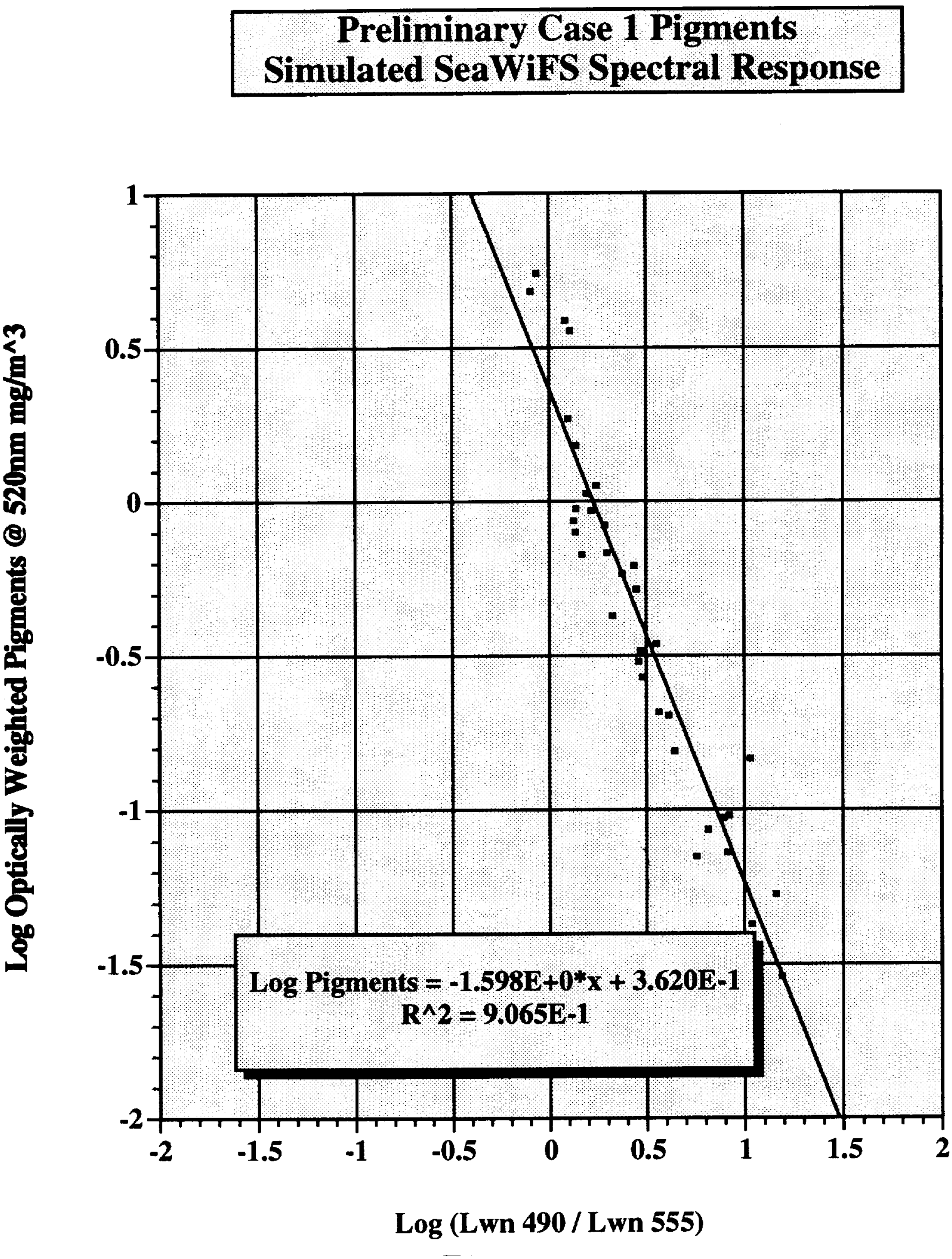

Preliminary Case 1 Pigments
Simulated SeaWiFS Spectral Response
Log Optically Weighted Pigments @ 520nm mg/m^3
1
0.5
0
-0.5
-1
-1.5
-2
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
Log Pigments = -1.598E+0*x + 3.620E-1
R^2 = 9.065E-1
Log (Lwn 490 / Lwn 555)

FIGURE 19

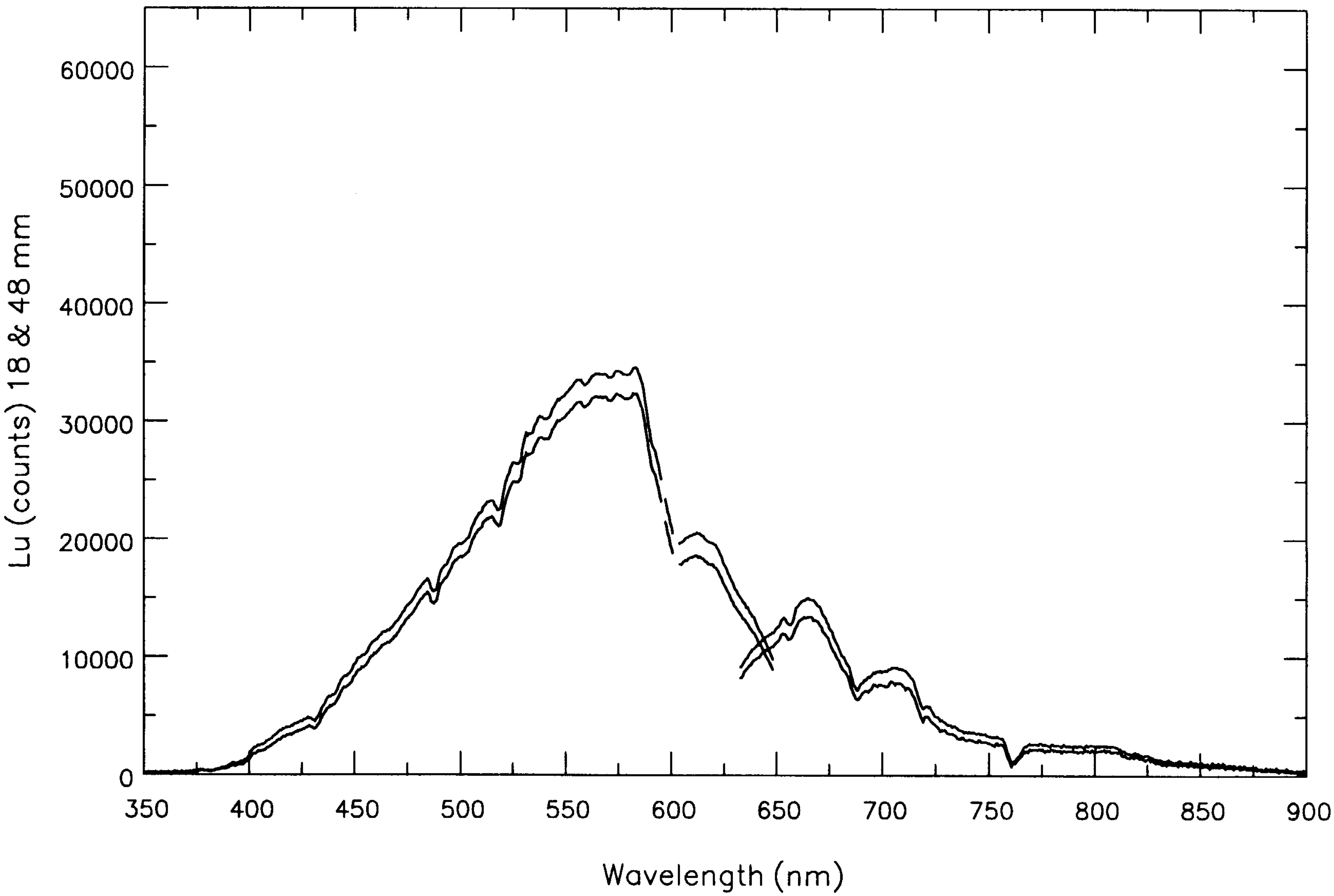


FIGURE 20

MLML 15 May 92

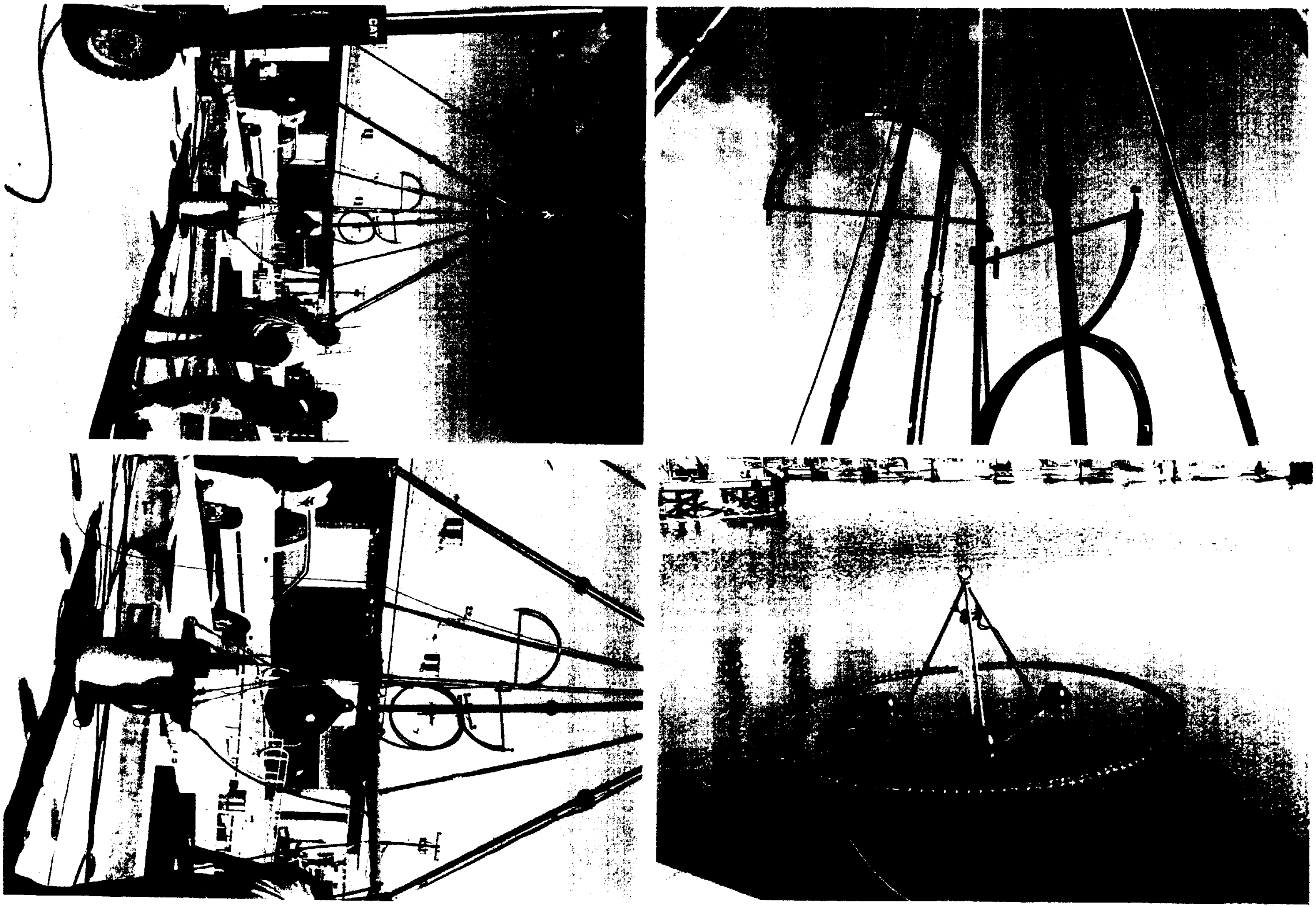


Figure 11. Radiometer trials in Moss Landing Harbor, 23 October 1991. Upper left and lower left: NOAA tetrahedron mooring with radiometer suspended below, note fiberoptic downwelled irradiance and upwelled radiance collectors; Upper right: Radiance and irradiance collectors; Lower right: tetrahedron buoy with wave-eaters, note absence of capillary waves inside wave-eater ring.

FIGURE 21

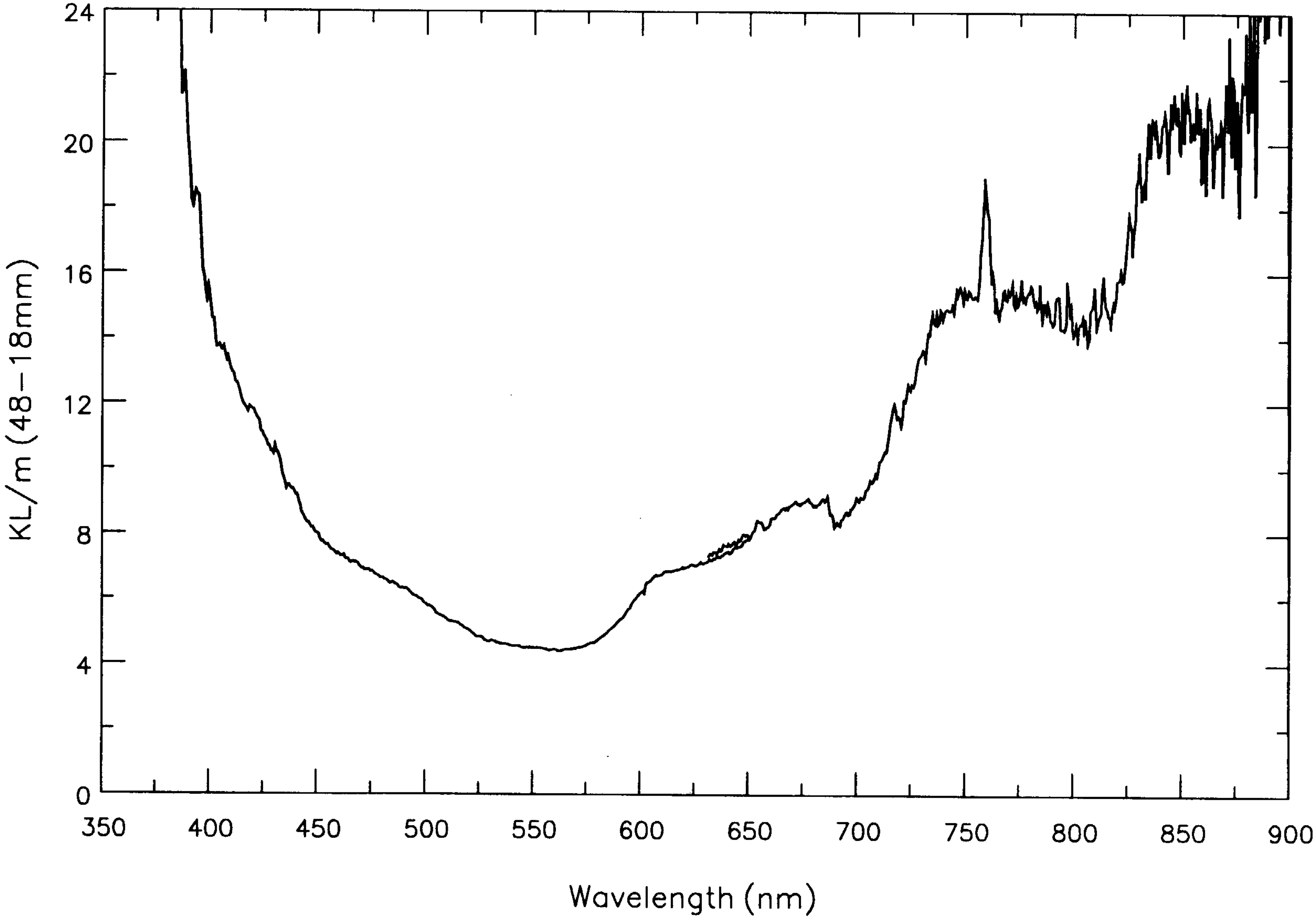


FIGURE 22

MLML 15 May 92

MOCE - 1 MONTEREY BAY
MOBY T&E AND BIO-OPTICS OPERATIONAL SCHEDULE

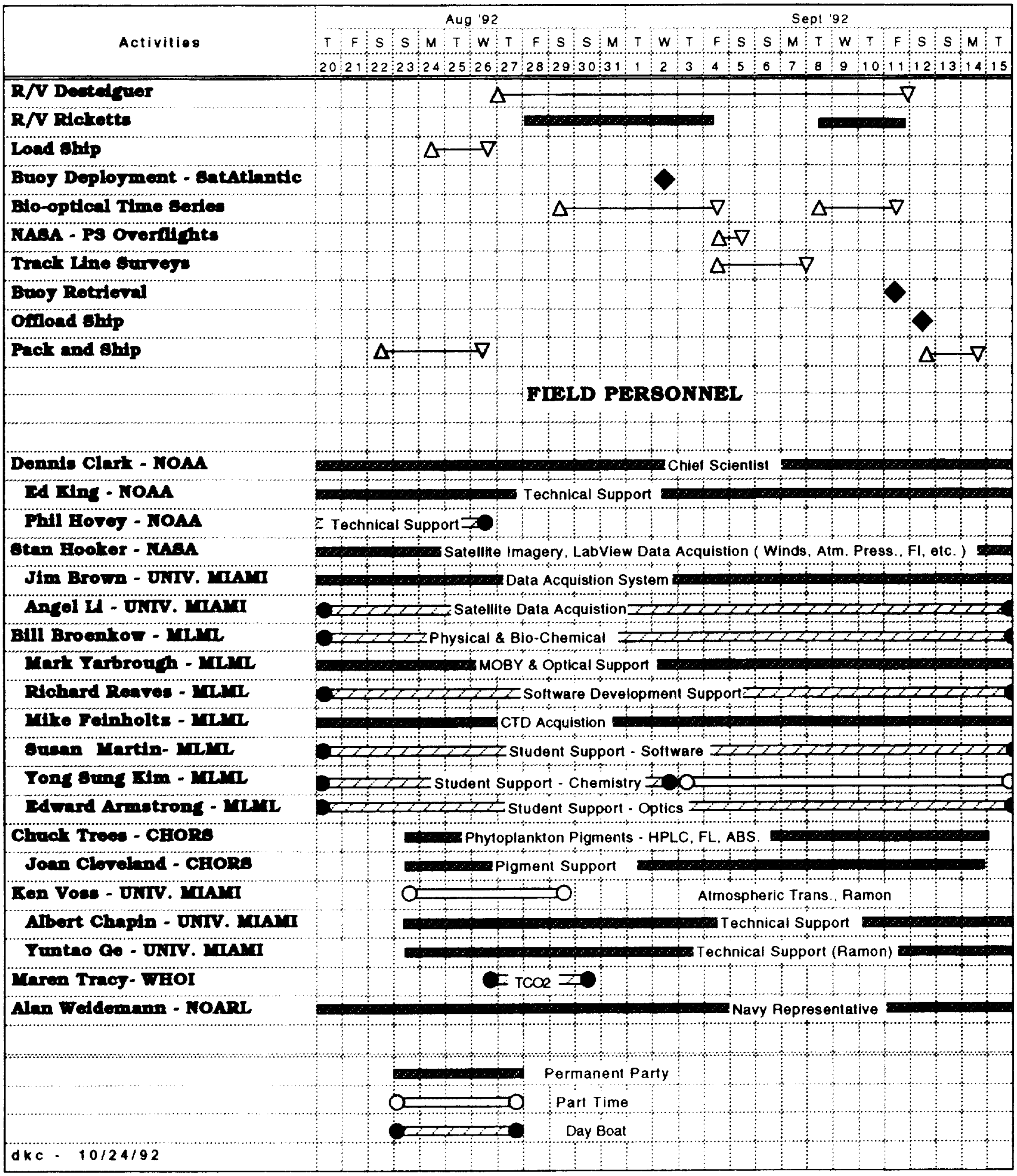


FIGURE 23

NOAA/MLML Spectroradiometer Data

CRUISE: MOCE-1 SHIP: USNS DeSteiguer
STATION: 1 - Monterey Bay

Sfc = 1 m
Mid = 5 m
Deep = 10 m

POSITION: 36° 44.6 N 121° 51.4 W
DATE: 16:04 (GMT) 04 Sep 1992

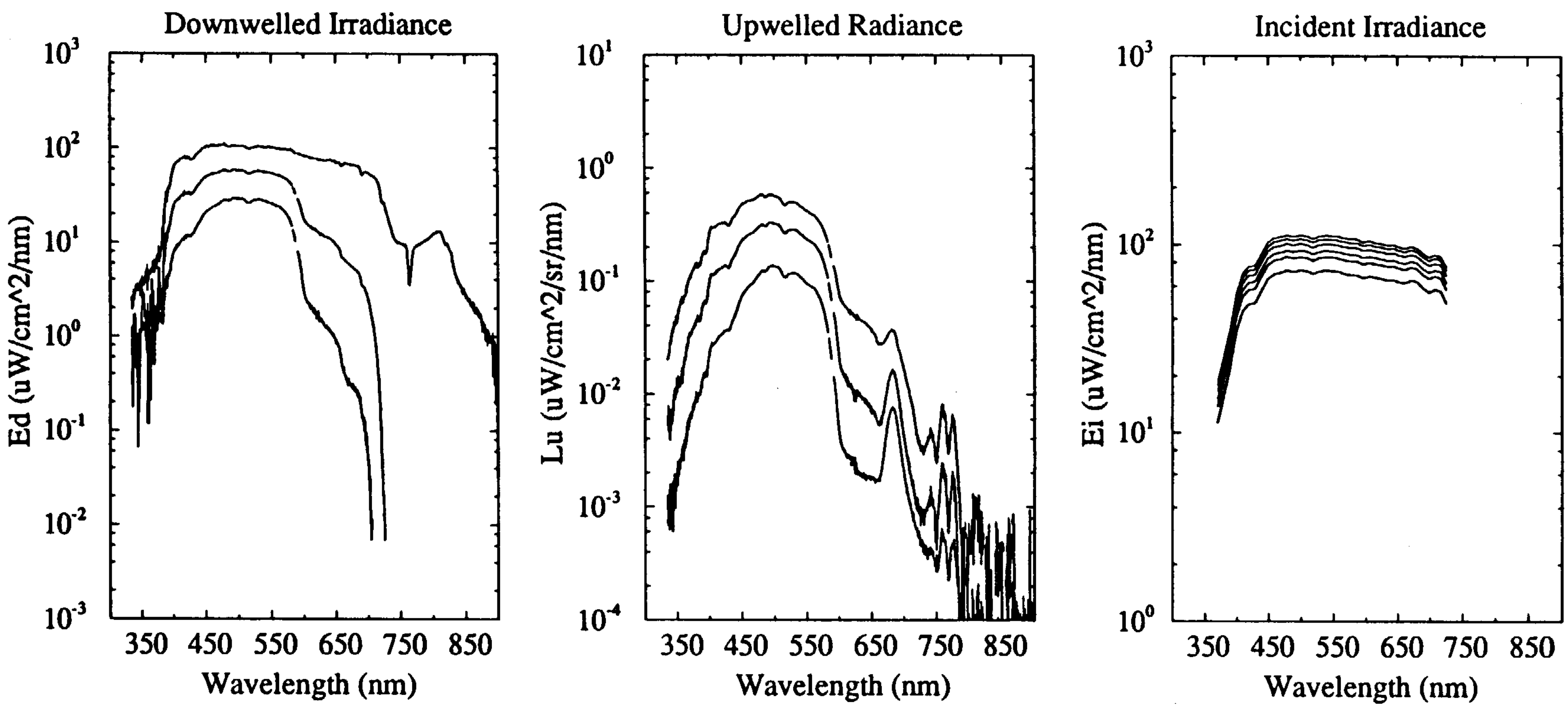


FIGURE 24

NOAA/MLML Spectroradiometer Data

CRUISE: MOCE-1 SHIP: USNS DeSteiguer
STATION: 1 - Monterey Bay

Sfc = 1 to 5 m
Mid = 1 to 10 m
Deep = 5 to 10 m

POSITION: 36° 44.6 N 121° 51.4 W
DATE: 16:04 (GMT) 04 Sep 1992

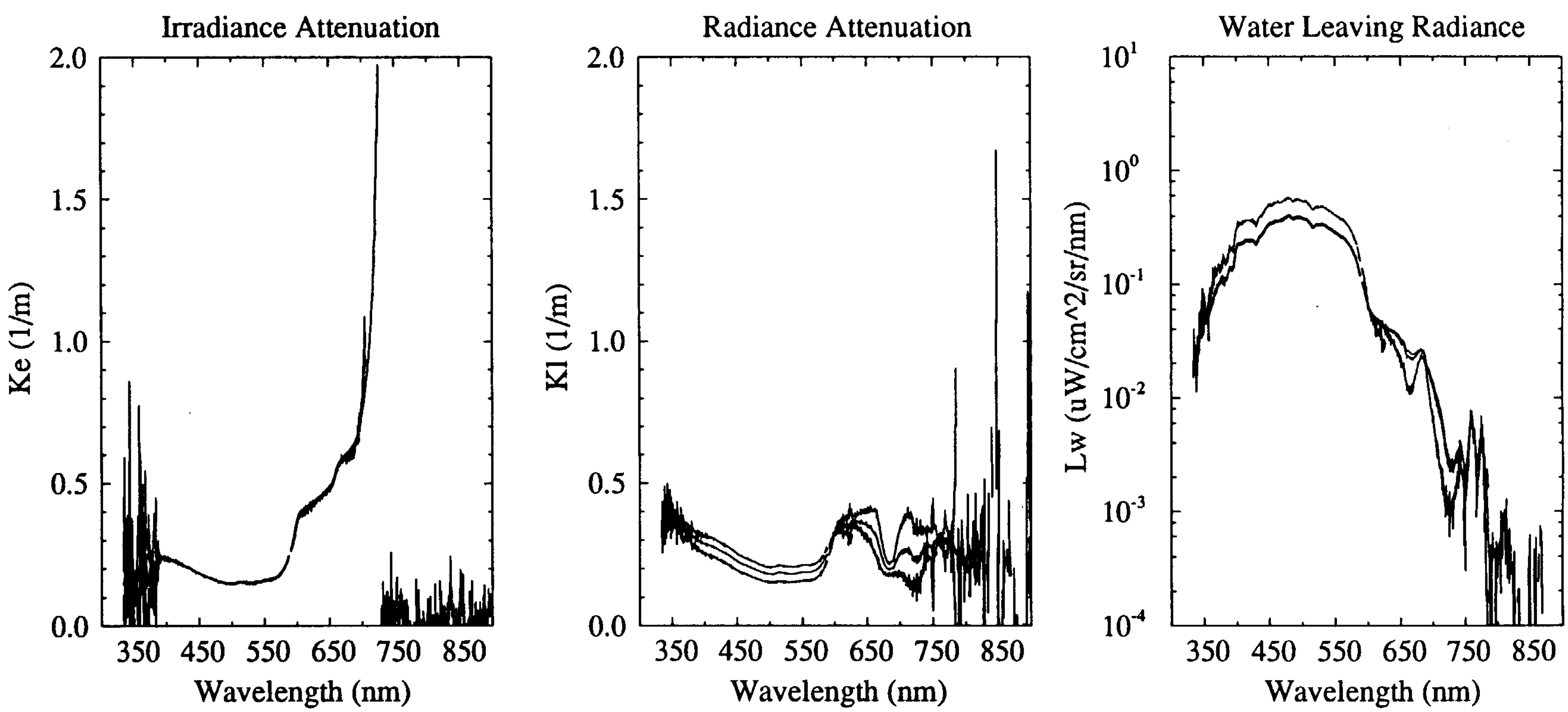


FIGURE 25

MOBY Header Data   Date: 21 Oct 1992

TT7 Time hh:mm:ss	Sutron Time hh:mm:ss	Sutron Volts (V)	Sutron Curr (A)	Battery #	Battery Volts (V)	Comp Dir (deg)	Tilt X (deg)	Tilt Y (deg)	Sea Temp (C)	Int Temp (C)	Press (db)	Array Temp Blue (C)	Array Temp Red (C)	Integ Time Blue (sec)	Integ Time Red (sec)	MUX Pos	Mir Pos
20:15:52	20:14:15	11.650	0.587	2	12.883	167.4	-4.0	-9.6	15.17	22.4	12.2	3.2	3.3	2.00	4.00	1	1
20:19:21	20:17:45	11.591	0.587	2	12.707	170.6	-4.9	-9.6	15.27	22.9	12.4	3.8	3.5	2.00	4.00	1	5
20:22:10	20:20:31	11.532	0.587	2	12.505	190.9	-3.5	-9.3	15.26	23.0	12.7	4.3	2.8	4.00	8.00	3	1
20:25:51	20:24:11	11.473	0.587	2	12.572	177.3	-5.0	-4.7	15.15	23.0	11.7	4.2	2.9	4.00	8.00	3	5
20:28:36	20:26:56	11.395	0.587	2	12.356	179.4	-5.7	-9.2	15.35	23.3	12.2	3.6	3.3	4.00	8.00	3	5
20:31:21	20:29:41	11.356	0.578	2	12.596	175.8	-4.9	-6.9	15.13	23.4	12.2	3.0	3.1	4.00	8.00	3	5
20:34:10	20:32:30	11.297	0.578	2	12.475	177.1	-4.7	-9.9	15.21	23.5	12.9	3.3	2.8	4.00	8.00	5	1
20:37:54	20:36:14	11.160	0.578	2	12.434	184.4	-6.2	-11.4	15.26	23.5	12.7	4.0	2.7	4.00	8.00	5	5
20:40:39	20:38:59	11.101	0.578	2	12.259	177.8	-3.0	-11.3	15.21	23.5	12.3	3.7	2.7	4.00	8.00	5	5
20:43:24	20:41:45	11.043	0.578	2	12.272	179.9	-4.7	-9.6	15.18	23.8	12.7	3.4	3.0	4.00	8.00	5	5
20:46:13	20:44:33	10.964	0.578	2	12.172	187.0	-5.4	-8.4	15.20	23.9	12.2	3.5	3.3	4.00	8.00	7	1
20:49:54	20:48:14	10.886	0.568	2	12.185	184.1	-5.8	-8.7	15.22	23.8	12.3	3.1	3.0	4.00	8.00	7	5
20:52:39	20:51:00	10.827	0.500	2	12.334	188.4	-3.6	-6.9	15.24	24.0	12.4	3.2	3.1	4.00	8.00	7	5
20:55:25	20:53:45	10.749	0.539	2	12.172	186.8	-4.9	-9.9	15.10	24.0	12.5	3.4	3.3	4.00	8.00	7	5
20:58:03	20:56:26	10.710	0.431	2	12.334	189.6	-5.4	-9.7	15.27	24.0	12.5	3.9	2.9	2.00	4.00	1	1
21:01:33	20:59:56	10.612	0.441	2	12.028	196.7	-6.6	-12.0	15.10	24.0	12.4	3.1	3.5	2.00	4.00	1	5
21:04:11	21:02:34	10.553	0.402	2	12.203	183.9	-5.0	-10.9	15.20	24.0	12.3	4.0	2.8	2.00	4.00	2	1
21:07:36	21:05:59	10.475	0.333	2	12.163	193.5	-5.1	-9.3	15.27	24.1	12.5	3.8	3.5	2.00	4.00	2	5
21:10:10	21:08:33	10.455	0.343	2	12.176	189.7	-5.8	-7.4	15.18	24.3	12.2	2.8	2.8	2.00	4.00	2	5
21:12:44	21:11:07	10.377	0.294	2	12.149	177.8	-6.0	-5.4	15.23	24.3	12.3	3.7	3.5	2.00	4.00	2	5
21:15:22	21:13:45	10.299	0.373	2	11.893	198.9	-6.3	-9.4	15.20	24.4	12.3	2.8	2.9	2.00	4.00	4	1
21:18:52	21:17:15	10.279	0.324	2	11.920	193.6	-4.7	-10.2	15.20	24.4	12.7	2.8	2.8	2.00	4.00	4	5
21:21:26	21:19:49	10.220	0.216	2	12.041	180.3	-5.6	-9.0	15.28	24.2	12.1	3.8	3.5	2.00	4.00	4	5
21:24:01	21:22:23	10.201	0.216	2	11.839	189.6	-5.9	-8.9	15.23	24.5	11.9	3.0	3.0	2.00	4.00	4	5
21:26:41	21:25:02	10.142	0.275	2	11.880	182.6	-5.7	-9.4	15.31	24.5	12.1	3.5	2.8	4.00	4.00	6	1
21:30:07	21:28:29	10.122	0.255	2	11.887	200.3	-5.8	-6.5	15.24	24.6	12.4	3.0	2.9	4.00	4.00	6	5
21:32:43	21:31:05	10.181	0.050	2	12.116	193.9	-4.4	-12.2	15.17	24.6	12.3	3.3	3.5	4.00	4.00	6	5
21:35:20	21:33:41	10.181	0.031	2	12.116	198.9	-5.5	-11.4	15.27	24.4	12.6	2.5	3.4	4.00	4.00	6	5
21:37:57	21:36:21	10.064	0.187	2	11.928	196.6	-5.4	-7.6	15.21	24.5	12.2	3.4	3.3	2.00	4.00	1	1
21:41:27	21:39:50	10.064	0.109	2	11.982	193.9	-6.0	-6.1	15.13	24.7	12.4	3.3	3.5	2.00	4.00	1	5
21:44:05	21:42:28	10.044	0.138	2	11.968	200.6	-5.4	-8.8	15.23	24.7	12.2	3.1	3.1	2.00	4.00	1	1

TABLE 1

APPENDIX:

MODIS FINANCIAL SUMMARIES

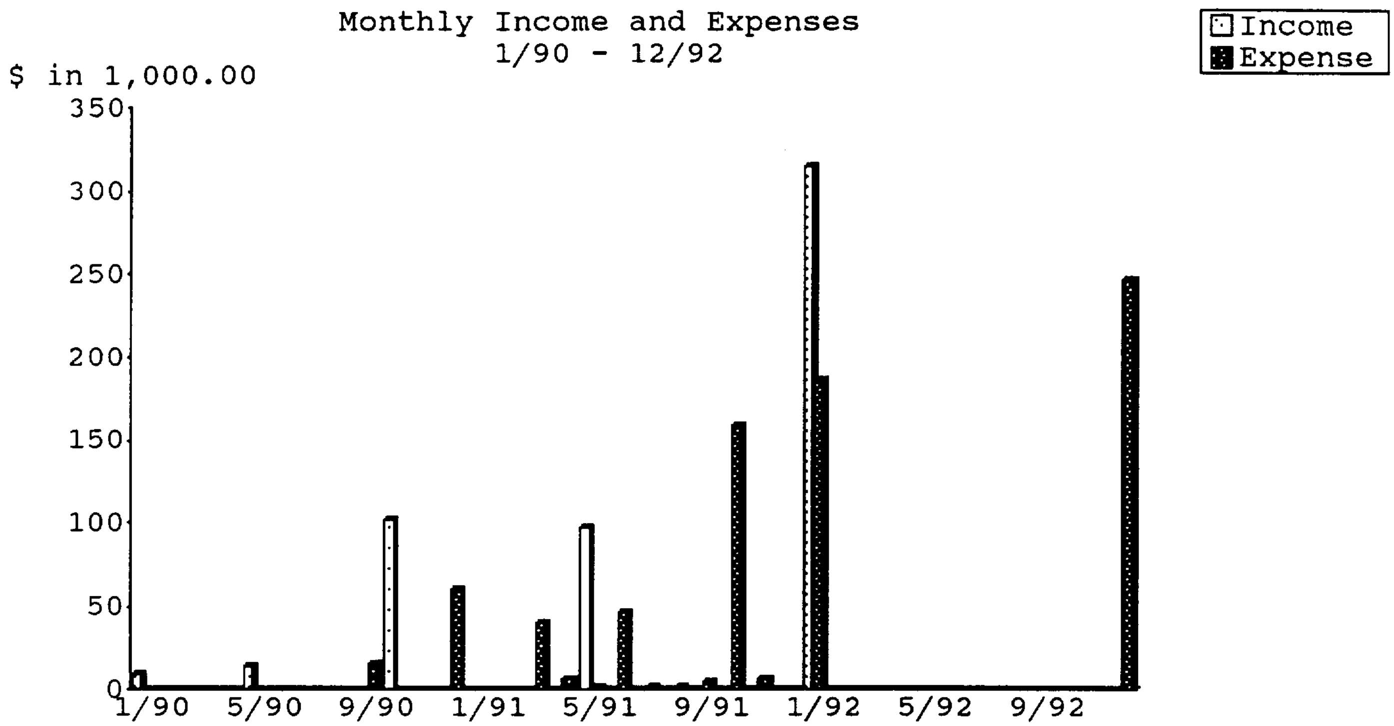
1990 - 1992

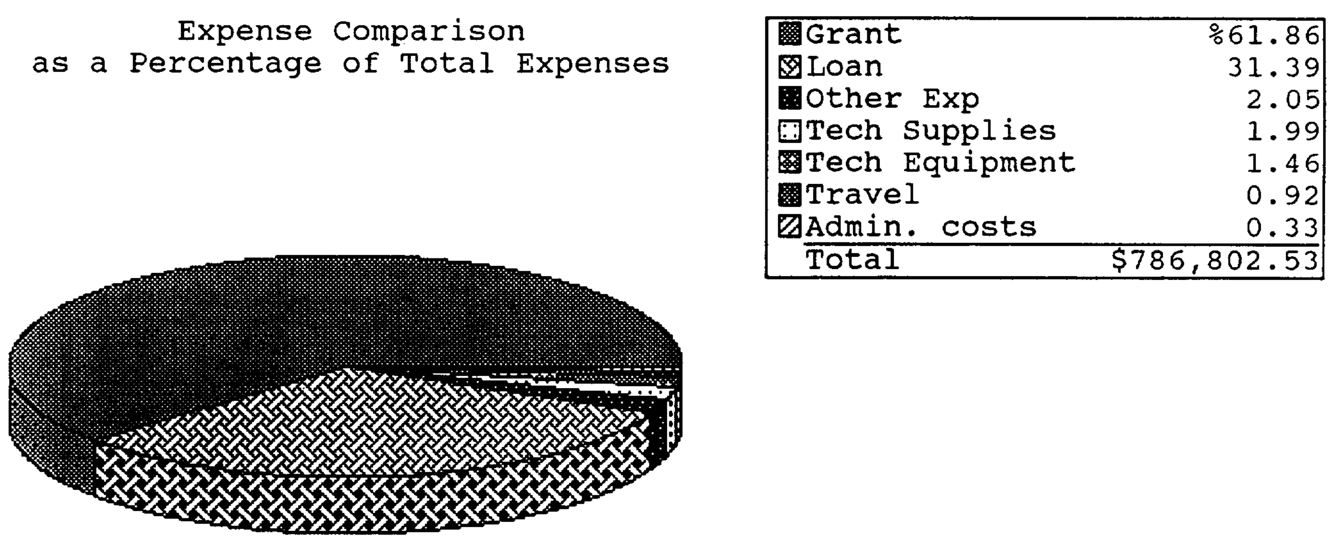
MARINE OPTICAL CHARACTERIZATIONS

DENNIS K CLARK
NOAA/NESDIS

MODIS Summary Report - D. Clark
1/1/90 Through 12/31/92

Category Description	1/1/90-12/31/92
INCOME/EXPENSE	
INCOME	
Funding source	540,000.00
TOTAL INCOME	540,000.00
EXPENSES	
Admin. costs	2,575.00
Grant	486,699.00
NOAA 8N2DP300 for MODIS	247,000.00
Other Expenses	16,124.48
Tech Equipment	11,493.15
Tech Supplies	15,643.59
Travel Expenses	7,267.31
TOTAL EXPENSES	786,802.53
TOTAL INCOME/EXPENSE	-246,802.53


Monthly Income and Expenses
1/90 - 12/92
Income
Expense
$ in 1,000.00
350
300
250
200
150
100
50
0
1/90
5/90
9/90
1/91
5/91
9/91
1/92
5/92
9/92


Expense Comparison
as a Percentage of Total Expenses
Grant %61.86
Loan 31.39
Other Exp 2.05
Tech Supplies 1.99
Tech Equipment 1.46
Travel 0.92
Admin. costs 0.33
Total $786,802.53

1/90 - 12/92

1/14/93
RN2D65(EOS-MOD)

Category Description	Other
INCOME/EXPENSE	
INCOME	
Funding source	315,000.00
TOTAL INCOME	315,000.00
EXPENSES	
Admin. costs	1,575.00
Grant	184,058.00
NOAA 8N2DP300 for MODIS	247,000.00
Tech Equipment	715.33
Tech Supplies	2,161.75
TOTAL EXPENSES	435,510.08
TOTAL INCOME/EXPENSE	-120,510.08

1991 MODIS - D. Clark
1/1/91 Through 12/31/91

Category Description	Other
INCOME/EXPENSE	
INCOME	
Funding source	97,500.00
TOTAL INCOME	97,500.00
EXPENSES	
Admin. costs	487.50
Grant	242,641.00
Tech Equipment	10,777.82
Tech Supplies	12,752.49
Travel Expenses	7,267.31
TOTAL EXPENSES	273,926.12
TOTAL INCOME/EXPENSE	-176,426.12

1990 MODIS - D. Clark
1/1/90 Through 12/31/90

Category Description	Other
INCOME/EXPENSE	
INCOME	
Funding source	127,500.00
TOTAL INCOME	127,500.00
EXPENSES	
Admin. costs	512.50
Grant	60,000.00
Tech Supplies	729.35
TOTAL EXPENSES	61,241.85
TOTAL INCOME/EXPENSE	66,258.15